

210
F00
179

A

**Review of Literature
OF COFFEE RESEARCH
in Indonesia**



415

by

P. J. S. Cramer



1971

00006574

~~001386~~

**A REVIEW OF LITERATURE OF COFFEE RESEARCH
IN INDONESIA**

By

**P. J. S. Cramer (1879-1952)
Director of Coffee Research
General Agricultural Experiment Station
(Algemein Proefstation voor de Landbouw)
Bogor (Buitenzorg) Java**

**Edited by Frederick L. Wellman
Plant Industry Department
Inter-American Institute of Agricultural Sciences**

**SIC Editorial
Inter-American Institute of Agricultural Sciences
Turrialba, Costa Rica
December 1957**



**Dr. P. J. S. Cramer (1879-1952)
Director of Coffee Research in Indonesia
General Agricultural Experiment Station
Bogor (Buitenzorg) Java
Indonesia**

Photograph taken in 1950, courtesy Mrs. Cramer

A REVIEW OF LITERATURE OF COFFEE RESEARCH IN INDONESIA
From about 1602 to 1945

Published by the Inter-American Institute of Agricultural Sciences of the O. A. S. It has been prepared as a service to the U. S. Operations Missions in Latin America, under the contract executed February 1, 1955 between the Institute and the International Cooperation Administration of the United States.

DEDICATION

For

Mrs. P. J. S. Cramer

How little do the millions throughout the civilized world, who sit at their breakfast-tables, realize the labor and pains which have been taken to place before them the fragrant cup which, if good, makes everything good.

Francis B. Thurber, 1881.

TABLE OF CONTENTS

| | |
|---|------|
| Foreword to the book - by Frederick L. Wellman | xiii |
| A note about the author - by Jorge León | xvii |
| CHAPTER 1. PLAN OF THE STUDY | |
| The Problem | 1 |
| General Books on Coffee | 1 |
| Purpose of This Book | 3 |
| CHAPTER 2. EARLY HISTORY | |
| Botanical Data | 6 |
| Government Planting in Indonesia | 7 |
| Private Producers in Indonesia | 8 |
| Research | 8 |
| CHAPTER 3. INTRODUCTION OF NEW SPECIES | |
| Coffea liberica | 12 |
| Coffea robusta | 12 |
| Other Species | 13 |
| Further Work | 14 |
| CHAPTER 4. TECHNIQUE OF PRODUCTION | |
| Seed and Nurseries | 16 |
| Transplanting | 17 |
| Planting Distance and Replanting | 18 |
| Topping and Pruning | 19 |
| Fertilizing and Leaf Composition | 21 |
| Upkeep | 23 |
| Green Manure Plants | 26 |
| Keeping the Humus | 27 |
| CHAPTER 5. THE CROP ON ESTATES | |
| Flowering of Coffee | 29 |
| Shedding and Overbearing | 30 |
| Relation Between Flowering and a Crop | 31 |
| Virescence or Abnormal, Abortive Flowers | 32 |
| Ripening and Harvesting | 32 |
| Curing | 33 |
| Drying and Further Finishing | 36 |
| CHAPTER 6. PRODUCTION BY NATIVES | |
| Planting Methods | 38 |
| Curing and Production | 39 |
| Improvement of the Native Production | |
| CHAPTER 7. LEAF DISEASE (Hemileia Rust) | |
| General | 41 |
| History | 41 |
| Hemileia on <i>C. arabica</i> | 43 |
| Leaf Disease on <i>C. liberica</i> | 43 |
| Leaf Disease on <i>C. robusta</i> and Other Species | 45 |
| Hemileia on Coffee Hybrids | 46 |
| CHAPTER 8. OTHER FUNGOID DISEASES | |
| Diseases of the Leaves | 48 |
| Corticium | 48 |
| Rhizoctonia Top-disease | 48 |
| Root Diseases | 49 |

CHAPTER 9. PESTS OF COFFEE

Nematodes 50

Berry Borer or Bessenboeboek 51

Branch Borers 54

Scale Insects 55

Dompolan Mealy Bug 56

Oerets or White Grub 57

Gangsir, the Indian Cricket 57

Xylotrechus 58

Wilt Disease or Phloem Necrosis 58

CHAPTER 10. GENERATIVE MULTIPLICATION

Flower Formation 59

Pollination 59

Round Beans or Pea Berry 61

Polyspermy 62

CHAPTER 11. VEGETATIVE PROPAGATION

Technique of Grafting 63

Grafting Under Tubes 64

Further Development 66

Advantages of Grafting 67

The Stock Problem 68

Choice of Grafting Wood 70

Grafting in the Field 72

Selective Grafting 73

Multiplications by Cuttings 74

CHAPTER 12. GROWING THE CROP

Soils 77

Rainfall and Winds 77

Altitude Above Sea Level 79

CHAPTER 13. THE SHADE PROBLEM

General 80

Erythrina 81

Albizzia 82

Leucaena glauca 83

Other Leucaenas 85

Other Shade Trees 86

Treatment of Shade 88

CHAPTER 14. COFFEA ARABICA

Characteristics 89

Closely Allied Species 90

Yield Figures 91

The So-called Degeneration 91

CHAPTER 15. VARIETIES OF ARABICA

General Remarks 95

Small Leaved Varieties 95

Varieties with One Divergent Characteristic 97

Varieties of Divergent Habit 98

Testing Forms 99

CHAPTER 16. IMPROVEMENT OF ARABICA COFFEE

Individual Yields 101

Special Strains 102

Forms for the Lower Arabian Belt 103

| | |
|--|-----|
| CHAPTER 17. COFFEA LIBERICA AND ALLIED SPECIES | |
| Characteristics and Origin | 105 |
| Popularity and Decline | 106 |
| Variability | 107 |
| Improvement of Planting Material | 107 |
| Closely Allied Species | 109 |
| Coffea excelsa and Allied Species | 110 |
| CHAPTER 18. COFFEA ROBUSTA - GENERAL | |
| Characteristics | 113 |
| The Introduced Trees | 114 |
| Combined Planting with Hevea | 114 |
| Variability of Robusta | 116 |
| Yield Figures of Commercial Plantings | 117 |
| CHAPTER 19. THE ROBUSTOID KINDS | |
| General | 119 |
| Quillou Coffee | 119 |
| Coffea canephora | 120 |
| Coffea ugandae | 120 |
| Other Kinds | 121 |
| CHAPTER 20. IMPROVEMENT AND DEGENERATION OF ROBUSTA | |
| Has Robusta Degenerated? | 122 |
| Improvement at Bangelan | 124 |
| Improvement by Private Institutes | 125 |
| Selection on Estates and the Nursery | 126 |
| CHAPTER 21. THE EFFECT OF SELECTION ON ROBUSTA | |
| Selection and Size of Bean | 128 |
| Effect on Productivity in General | 128 |
| Effect on Yield in Seedlings | 130 |
| Effect on Yield of Grafts | 132 |
| CHAPTER 22. VARIOUS SPECIES | |
| Coffea stenophylla | 135 |
| Coffea affinis | 136 |
| Coffea congensis | 136 |
| Coffea eugenioides | 138 |
| Kapakata Coffee | 139 |
| "Botanical" Species | 139 |
| CHAPTER 23. THE DIVERSITY OF FORMS | |
| The Conception of "Species" in Coffees | 141 |
| Group of Allied Species | 141 |
| Spontaneous Hybrids | 143 |
| Introduction from the Wild | 144 |
| The Search for Resistant Forms | 145 |
| CHAPTER 24. CHROMOSOME STUDIES | |
| History | 147 |
| The Bullata and Monosperma Varieties | 148 |
| Chromosomes and Number of Stomata | 150 |
| Chromosome Numbers | 150 |
| CHAPTER 25. HYBRIDS BETWEEN DISTANT SPECIES | |
| Seedling Variation | 153 |
| Hybrids of Arabica with Liberica | 154 |
| Hybrids of Robusta with Liberioids | 155 |
| Stenophylla Hybrids | 156 |

| | |
|--|------------|
| Congensis Hybrids | 156 |
| Hybrids of Arabica with Robustoids | 159 |
| Kapakata Hybrids | 161 |
| CHAPTER 26. HYBRIDS WITHIN THE GROUP | |
| Arabica Group | 162 |
| Liberica Group | 162 |
| Robusta Group | 162 |
| Further Development | 163 |
| CHAPTER 27. THE MARKET PRODUCT | |
| Storing the Market Product | 165 |
| Coffee on the Market | 165 |
| The Trade in Native Coffee | 167 |
| Government Help to Producers | 168 |
| Caffeine Content | 168 |
| Taste and Flavor | 170 |
| Roasting and Substitutes | 171 |
| Making the Beverage | 173 |
| CHAPTER 28. BYPRODUCTS OF COFFEE | |
| Substitutes for Market Coffee | 174 |
| Tea from Coffee Leaves | 175 |
| Other Byproducts | 175 |
| CHAPTER 29. INDONESIAN COFFEE IN THE MARKET | |
| World Production | 177 |
| The Production of Indonesia | 177 |
| Production of Various Kinds | 178 |
| Local Consumption and Exports | 178 |
| Area Under Coffee | 179 |
| LIST OF LITERATURE CITED | 181 |
| INDEX | 225 |

FOREWORD TO THE BOOK

Frederick L. Wellman, Editor
Senior Plant Pathologist
Inter American Institute of Agricultural Sciences

We know that the story of coffee goes back to ancient history. The first possible knowledge of it in the civilized world was probably in the fifth and sixth centuries, when the old Persian invaders picked some of it up as part of their loot in their extended sallies into forbidden parts of northeast Africa. The first of it went into sorcery and medicine. Coffee as a pleasure drink did not become of more than shadowy fame until the Mahometans took it for their own special exploitation. It spread to the easternmost edges of Europe, and that is where the valiant Dutch came in, because at the same time, they were seeking a firm place in the commercial sun.

It was for the purpose of strengthening and solidifying the Netherlands holding in southeast Asia that the Dutch East India Company had been founded in 1602. They needed trade. This meant shipping, for they represented a supremely maritime nation and the Company itself had 70 vessels in its first year. These were agricultural islands they had, and a relatively stable crop that produced a concentrated product, was the great desire. Coffee was being paid for almost like gold, and the Dutch traders set out to study it and do what they could do make it serve them. They brought it to Java as soon as they could settle themselves.

The history of coffee cultivation in Indonesia is a long one. The Dutch had signed a treaty with the Sultan of Bantam, in the westernmost part of Java, in the year 1597. It was on the basis of that, and the rich volcanic slopes, that the Dutch saw this could be not only a beautiful land but a wonderously wealthy agricultural spot. Taking those things into account was part of the reason the Netherlands States-General gave a charter to the Dutch East India Company 5 years later. There had been in progress a long tussel between the French, English, and Hollanders for supremacy in the East Indies. The Dutch had won their place, and they settled in Indonesia.

It was quickly recognized by them that their success as a colonial power had to be based upon agricultural enterprise. It required a product from the soil that was wanted in the centers of populations, that had not only a good value but could be shipped without deterioration, that could be kept in storage for extended periods in the holds of ships, and that could be grown in the tropic lands they were developing. They saw this in coffee. Coffee houses were busily humming in the great cities of Europe and the Near East, and the Dutch were furnishing much of the coffee used. For decades the Dutch orient merchantmen had been taking for sale what was known as the Turkey Berry, from the bazaars of such ports as Constantinople, Grand Cairo, Mocha and Alexandria. As they sailed from place to place, Dutch sea captains themselves made acute observations to help in the growing and production of coffee. In addition, occasionally they took with them, men trained in botany and medicine, who looked at coffee from a professional point of view. In actuality, the first observations and research in coffee, using the methods of science as it was known in those days, had been accomplished years before 1602. However, for a long time it was thought that coffee could only come from the Near East.

In Java during the decades 1680 to 1700 more advanced study on coffee, and its planting, was being carried on, and by 1711 a first lot of 102 pounds of clean market coffee was sold to the Dutch East India Company in Java. It had been found to grow well and it was not long before repeated sales had been made of the aromatic grain from cultivated trees, and it became an established business in Amsterdam. The reason for the firm establishment of this market in Holland, was that the Dutch were bringing it in without fail, year after year. It was attracting an ever widening public. It had become of high value not only to the sellers in Europe, but also to the merchant fleet that sailed to foreign ports, and to the agriculturists that lived in the tropical islands. To insure their business, the Dutch began the use of newly discovered methods in science, to develop their agricultural regions. They looked far into the future.

The estate owners of Indonesia, started their own individual studies to aid in technological developments. These studies paid so well that soon the planters were being assisted by their East India Company, and then their own government of the Netherlands Indies. The results were better production and confidence in the future. The settlers built gracious homes in their beautiful surroundings, their fields they called coffee gardens, "Koffietuinen", and they constructed cities with clubs, theaters, and markets. They were permanently part of the land. These were no longer adventurers, but soil loving farmers, and special farmers of an aristocratic type. With high intelligence they insured their success by taxing themselves to hire the best scientific brains they could secure to work on their agricultural problems. They built numerous scientific institutes and agricultural

experiment stations. They were not afraid to put money into science because it paid them, and seeing that it was important they published their findings.

These publications from Indonesia have been passed over too easily in the western hemisphere, with the often repeated but fragile excuse that the language the Hollanders used in describing their work in Indonesia was too difficult for our eyes. We kept more comfortably to our pages of Spanish, French, Portuguese and English. There have been a few investigators in coffee who were not born Dutch, who have worked with the Dutch language publications and gained great value for their research. Most of us have struggled unnecessarily with techniques, ideas, problems and programs because we did not have previous knowledge of what had already been done in the Netherlandisch science reports relating to coffee. We can read about these now in this comprehensive review by one of the great masters, P. J. S. Cramer. We are indeed fortunate as the reader will soon learn, and we can never be too thankful for his collating it for us.

For too long we have been unaware of work done and problems solved by the Dutch. Here are just a few examples. Over a hundred years ago workers in Indonesia were exploring problems relating to soils and coffee. Some fifty years later they had drawn up considered reasoning about the importance of humus to coffee. They worked with sun grown coffee, so long ago that we have only inferences concerning it, and no sure dates. After years in the sun, they put it back under light shade. Under their conditions they preferred shade and the work on it in comparison with the older growing in the sun, was such ancient history that it lost its controversial character even as a conversation piece. All coffee to be grown in Java was placed under shade as a matter of course. The importance of shade trees was accepted and so well recognized that Cramer does not even discuss it as a questionable matter in this book.

As another example, various planting distances were tested, and close spacing was discarded by the Indonesian workers before the beginning of our present century. They still were intrigued with the idea of more trees on a unit of land, and once again returned to the problem of growing their trees in "belts", with greater spaces in land between. This problem is the same as the so-called "hedge" planting studies we are studying in Latin America. They closed out their work on belt planting as unprofitable, as plantings aged under their conditions. The last of this was published in 1936.

To the specialist who is at work on the Arabica variety, it may come as a disappointment that this book by Cramer is mostly about the Robusta variety. During the period when Cramer had so much to do both administratively and in research, Robusta coffee was most grown as it is now, in Indonesia. In fact in the years around 1930 to 1940, approximately 94 per cent of the coffee was Robusta, 3 per cent Arabica, $1\frac{1}{2}$ per cent Liberica and Excelsa, and $1\frac{1}{2}$ per cent "other sorts". Indonesia produced 6 per cent of the coffee for world trade, and was the third country producer. It is for such reasons that this book is largely about research on the species *Coffea canephora* which includes the variety Robusta.

However, there are parts of this book specifically on *C. arabica*. Most important, this book is packed full with descriptions on problems solved on coffee, and suggest how they were solved. The citations about techniques included are multitudinous. At no time, before or since, has there been as continuous careful work done, or as good understanding developed, about the coffee trees, as came out under the Dutch horticulturists. They had been forced to stop most of the growing of *C. arabica* shortly before and after 1900 because of the terrible infection of the Rust. Nothing daunted, they searched for resistance in other coffees, and found it in selections from varieties of the Robusta strain of *C. canephora*. Most of these selections were tolerant in nature, varying in disease reactions to the point of being highly resistant in some, and of superior vigour and productivity.

These scientists were men with "green thumbs", and they made virtue out of necessity. They turned to Robusta, and liked the tree. Where it had been passed off because it had such small beans they bred and selected types with beans to suit the market. Where quality of Robusta was once thought of as far below basic likes in the world, they isolated strains that were not only good natural blending coffees, but some that by themselves stood the test for fair cup quality. They did not have all of the aroma of *C. arabica*, but were better than the common Robustas and were drinkable, filled a place, and had a future. These quality selection studies were just under way when the war stopped their progress.

The work done in Indonesia on tropical soils is unbeatable for their time. By application of scientific findings the farmers results are outstanding in Indonesia, in preserving their tropical terrain and carrying on profitable agriculture on it year by year, and into the centuries, so that the people of the land could settle and see a future in their permanent communities. The research in Indonesia is of top quality on "green manurers", the use of Leguminosae to be sure, and research also on the root competition of these Legumes with coffee and in some instances actual toxicity. "Those scientists were mulch mad" as one of them expressed it to me. They studied what

a shade trees gave to the soil, what tonnages of debris contained in actual nutrition from different tree and herbaceous species. Under some conditions, they cultivated, for mulch, weeds and annuals more often thought of as ornamentals, such as species of Ageratum and Salvia. They correlated all this work with coffee physiology.

There has been no group of coffee research men who worked so industriously or so continuously on coffee physiology, as those in Indonesia. Technology of production in the field depended especially upon what they found. They were the ones who pointed out that the coffee leaf is a storage organ, and that the crop draws upon it. Their work on foliar analysis, coupled with studies on the changes in leaf, branch, stem, and fruit content over periods of time, threw great light upon coffee tree development and productivity. While this was done on Robusta, it is all highly suggestive for Arabica.

Through settling upon the use of shade for the fertility it gave to grow both their Robusta and Arabica crops, the Indonesian coffee farmers had plantations remarkably free from minor element deficiencies. But deficiency troubles did occur and works on them were published a few decades ago. In the same manner, the earliest, and for its time the most complete works on certain coffee diseases and insects, were done in Indonesia, although only a minimum of it is discussed by Cramer. While other coffee producing countries have worried about how they could possibly control root disease nematodes, research institutes of Java, by selection for root resistance and by grafting, were growing large crops in lands literally alive with the organisms.

Pruning is another problem the researchers in Indonesia studied, and they published their results. They analyzed and understood the morphology of the tree, bud differences, and effects from season and nutrition. Cramer was especially interested in this. They determined what kinds of growth resulted at different altitudes and exposures, what the time of cutting had to do with following growth responses, and the matter of rotation of uprights. They tested long ago, effects of no pruning or free growth against tree control, and studied the economics of pruning against growth without it. In connection with all this, they also knew more about vegetative propagation and effects of budding, graft compatibilities and the grafting art, than any group of coffee horticulturists that have ever worked anywhere.

Nowhere did coffee breeding and selection rise to such refinement and importance as among the Dutch and Indonesian workers. That it is still in progress in Indonesia, indicates the successful training which the Netherlands scientists had given their local counter parts before the war. Another point should be mentioned. The Dutch were obsessed with making all their scientific advances pay if they were used either by Europeans or only the natives. They did a lot for purely technical information, but they did not advise any new method until their farm management specialists had shown that it paid well. They published on all phases of costs of the new methods, and returns from their employment.

A word about the coffee research literature from Indonesia. First, it is a notable thing that so much publishing was done. Mostly it was paid for by private subscriptions to journals and it appeared in scientific periodicals some of which dealt exclusively with coffee. If you were a coffee technician you had to publish. The growers expected it and this was why they paid your salary. There was a pride and a stimulus and a professional recognition from articles published. Occasionally, even the plainest of the growers, all of whom lived in their coffee gardens, may have kept such good records and were so full of their knowledge of their specialty, that they were also asked to publish their findings.

These many technical studies, farmer's reports, meeting proceedings, experiment station reviews, news notes from the research fields, all went into a series of well edited journals. Some of these are: MEDEDEELINGEN S'LANDS PLANTENTUIN, BERGCULTURES, INDISCHE MERCUUR, ARCHIEF VOOR DIE KOFFIECULTUUR, TEYSMANNIA, TIDSCHRIFT VOOR LANDEN TUINBOUW EN BOSHCULTUUR, ANNALES DE JARDIN BOTANIQUE BUITENZORG, and LANDBOUW. Journals such as these ran for centuries, and these are the predecessors of our own scientific agricultural journals when the present century began. They all had strong followings.

The first publication cited by Cramer is dated 1861. What had been studied before was not as scholarly as that which came later. The old findings were more or less farm knowledge, but the long background over two and a half centuries of information, was referred to and results crept into the succeeding publications and recorded discussions. It is of significant interest to examine the chronology of the publications used in this book. Some 177 publications were cited by Cramer, from 1861 to 1900. In the following 15 years there were 220 publications which he used, and in the next 15 year period following that, he chose 265 to review. The growth of the greater intensity of interest and the leadership evolving in Indonesia is notable from the fact that Cramer cited a total of 283 important publications from the 5 year period of 1933 to 1938. And the succeeding 7 years, even broken as it was by the war, resulted in citations of over a hundred articles. Of nearly 1100 ar-

ticles, many of which he cited numerous times, close to 90 per cent of what Cramer reviewed was Dutch work. Almost all of that has heretofore hardly been touched by the rest of the coffee workers in the world. That is why this Literature Review by Cramer is such a gold mine for agricultural workers who do not read Dutch.

Some of the Dutch names of the scientists that will appear in the following pages, at first may seem strange to readers of other languages. On studying this book they will be found again and again and will become familiar. There are, indeed, those we already have heard of in other parts of the Tropics. For example, Ferwerda, the coffee breeder, Roelofson, and Coolhaas, and Schweizer the physiologists. Bally, known for his disease work, and the meteorologist Braak. So many, through their publications, show their stature. It is not wise to mention a list on that basis, but some of wide interest continue as follows.

A controversial figure, as a botanist, was De Wildeman. Though he was French, he worked a great deal with the Dutch materials, and with the Dutch scientists. His contributions helped greatly to clarify the basis of the modern concept of species in the genus Coffea. Forty years ago a morphologist by the name of von Faber delved into how the buds and flowers developed in relation to the coffee tree's morphology and physiology. Huitema studied the way in which coffee growing could aid in the evolvement of under developed people. One geneticist, with wider interests than many, was the man with a triple name, Hille Ris Lambers. Gandrup directed a station but he also published studies and observations along with the rest of his research colleagues. There is a whole list of hundreds of outstanding Dutch names some of the colorful being van Delden Laerne, the explorer and economist, van den Berg, also an economist, and the chemist-physiologist, van der Veen.

Special mention should be made of J. G. Kramers. He was the predecessor of our author in his position, but, their names although similar, should not be confused. Kramers apparently did much to lay the foundations of the newer types of research in coffee. He may have been a man of the old school, and a man with an iron will, but he brought in new plans and new workers. He would introduce a new specialist to this physical environment, to his laboratory, to his field, and to his problem. After that the specialist was informed that this was his life, and this was his responsibility from which the growers expected a guarantee of results. Without results the specialist could not hope to retain his position. Moreover, Kramers lived up to his own requirements of others. The hours were long and often the weeks never ended, but it was stimulating and exciting and it resulted in some of the greatest advances in tropical science.

Finally we come to P. S. J. Cramer. He was brought to Indonesia, a vigorous young man 26 years old. He was living under the spell and influence of his great teacher in Amsterdam, the man of towering concepts, who first conceived of mutations in plants, the classic Hugo De Vries. It is said of Cramer that, forever he was always lucid and full of information on plant variability problems in relation to agriculture. His work in Indonesia was first on the variability problem and the species concept in Coffea. Later he had to work on more than that, but, after all, his first interest was the species problem. His associates describe him as a modest man, gentle, but strong and a vigorous worker. When he was director over the agricultural work of Indonesia he visited all the stations as often as he could. Morale was kept high. He fought for his men. He required results from them. He required publications from them and from himself.

He started his work in Java in 1905, and carried it on throughout Indonesia for 37 years, with occasional consultation trips away, until sometime in 1942. Then he was captured and made a war prisoner for 3 years. Even under those most difficult conditions, he never lost his interest in the problems of tropical agriculture. In between times of trouble he was given access to the library in Indonesia and he wrote this book, and some others as well.

He was a master!

A NOTE ABOUT DR. P. J. S. CRAMER, THE AUTHOR OF THIS BOOK

Jorge León, Head
Plant Industry Department
Inter American Institute of Agricultural Sciences

The author of this book reviewing some centuries of research on coffee in Indonesia, was one of the best known and most highly respected men in the science of his time in Tropical Agriculture. Dr. P. J. S. Cramer was a great man in his studies, in his difficult administrative capacities, and in his research and publications. In the last years, he had an amazing career as counsellor and adviser to various private companies, research experiment stations, and governments. He had a wide list of specialities in the cultivation and elaboration of many tropical crops, notably oil palm, hevea rubber and the coffees.

P. J. S. Cramer, was born in Lonneker, Holland on the 29th. of November, 1879. It is of significance that his higher education was under the personal supervision of the well known Dutch botanist, Hugo de Vries. He acted as assistant to Professor de Vries on those beginning studies that eventually led to the theory of mutations in plants.

At the age of 26 years, Cramer started in 1905 his researches in tropical crops. His first special work was in the botanical laboratories of Buitenzorg in Java. For a good many years he concentrated his attention on the challenging problem of the many forms in coffee, and their relations to the improvement of the crop. The result was his classic work "Gegevens over de Variabiliteit van in Nederlandsch Indie Verbouwde Koffiesoorten", published in 1913. Meanwhile, from 1910 to 1912, he had served as Director of the Department of Agriculture of Surinam and started work on Hevea. There he was able to demonstrate the wide variability in this plant, and as in Robusta coffee, the necessity for resorting to vegetative multiplication through buds and grafts to produce ample quantities of trees of both uniformity and high productivity. Somewhat later he perfected his technique called "Textatest" for the evaluation of the amount of latex from test on young plants of rubber.

During his last years, Cramer carried on extraordinary activity as a consultant. During that time his visits included Malaya, Trinidad, the Guianas, the United States of America, Japan, Hawaii, Ahnnan, Tonkin, Belgian Congo, Ceylon and some other places. From 1937 on he worked and maintained connections with the School of Agriculture in Wageningen, Holland, and in the University of Utrecht. He died in Vasenaar on 23 of March, 1952.

He was able to combine, as few have, the capacity of the pure scientist in research and teaching, with the applied phases of a consultant who made practical recommendations to private or governmental enterprises. He was widely known for his many publications. His fundamental study on variability in coffee, and problems connected with selection of this plant, make a classic work, of such value that it should be referred to repeatedly by the serious investigator on this crop.

CHAPTER I
PLAN OF THE STUDY

THE PROBLEM

Coffee planting in Indonesia presents many problems. Since the decade of 1870-1880, when the planting industry was put on a scientific basis, many workers have studied the problems and sought solutions for them. However, the subject is so complex and the issues so numerous that there remains a feeling of dissatisfaction and doubt despite all that has been achieved. It has led to the cri de coeur of one of the leading planters, the late N. M. de Ligt (Notulen, 1940, p. 1608), who asked how much real progress had been made in the last 28 years. This question led to several discussions and lectures by leading workers in the coffee research institutes. Their attempts to provide an answer were based more on theoretical considerations than on actual comparative statistics covering average yields over a period of time.

To judge from the widespread attention which de Ligt's question attracted, it may be concluded that he touched a sensitive point of general interest, probably because he expressed the feeling of uncertainty current among planters as well as research workers. One of the latter (Schweizer, 1932, p. 452) had already pointed out some years earlier that the question of seedling or budgraft in the case of rubber had not yet been answered definitely in spite of years of study. Why was it that this question had never been asked in the case of coffee? It seems plausible to conclude that it is due to the fact that it has been so much easier to get practical results from seed selection in the case of coffee.

The author proposes only to contribute some data through a review of the literature, very largely from Indonesia, to a solution of the problem by reviewing the earlier periods of the industry where so much has been done. To make all this information accessible and comprehensible for the reader who is not acquainted with coffee growing and curing, it is necessary to give a general description of the process of production "from plantation to cup", as an older author, Thurber, called his book, published in 1881.

We might well wish that he could return and describe all that he saw and heard in the principal coffee-producing countries. Although methods and materials have changed radically since his day, Thurber would probably still dedicate his book "to the man at Poughkeepsie, who keeps the railroad refreshment rooms... I do not know his name, but year in and year out he gives the public an ideal cup of coffee. One of the chosen few who know how to make a good cup of coffee".

GENERAL BOOKS ON COFFEE

There are several books giving general descriptions of the whole process of coffee production, the majority of which were published in Indonesia. The chapter on coffee by Kamerling in van Gorkom's Groote Cultures (1918) and the volume by Hagen on the subject in Onze Koloniale Landbouw (1917) might be cited. Both give a good general description, but neither is up to date, and neither gives the details which are of interest to the research worker. Excellent pictures of coffee are contained in De Groote Cultures der Wereld, Chapter VIII (van Someren Brand, 1916, p. 278), but his information is not always correct and is occasionally obsolete, for instance, when he states that Coffea liberica occupies a fourth of the plantings in Indonesia (loc. cit., p. 288). Actually it had already been replaced by C. robusta.[†] Andrade (1914) wrote an excellent review of the state of the industry after a visit to Indonesia in 1913. An old book in German is Pesca's Der Kaffee (1904), an exception among the older works in that it gives attention to grafting in Java (Pesca, p. 235). He does not, however, understand the commercial importance of the newer varieties such as Robusta (called C. canephora var. kouluensis). Since then some aspects of the problems have changed and new ones have arisen. Zimmermann (1928) is more modern, but his treatment of the more recent developments is too brief. Bally's methodical review of the world literature on coffee in 1931 and 1932 is full of information, but it has not been followed by a recent study of similar proportions. A very complete work on the whole modern technique in Indonesia is the "Vraagbaak voor de Koffiecultuur" (1941), a work designed as a reliable handbook for the planter. It is a model for this type of work and is concise and complete, but it is obvious that subjects about which uncertainty still prevails cannot be included in the scope of such a vade mecum. It replaces Morren's Handleiding (1896), and excel-

[†] There is considerable argument as to botanical nomenclature in coffee, and it is not settled.

The usages in this review are not necessarily those accepted on all sides, but they are commonly employed by some. In recent times we consider that the coffee known as Robusta comes as a variety under the species Coffea canephora Froehn. It will be observed in this book that, for example, C. canephora var. kouluensis and variants of that name; C. canephora var. ugandae; C. canephora var. robusta; crosses between them and others of these species, are sometimes included as Robustas. In many cases Cramer used the binomial Coffea robusta. The nomenclature in this book is employed in the sense in which Cramer wrote it, and not especially as we conceive of it. F. L. W.

lent book in its day. Although antiquated, it contains some hints on plantation management that are still useful. A few other books published as coffee planters manuals may have some value, but they are wholly obsolete and of little historical interest. For example, in Dutch are the manuals by de Munnick (1843 and 1863), a report by van Spall on Ceylon (1861), Steinmetz (1865), the Handling of 1873, de Sturler (no date), and Prins (1878). In addition, we have Brown (1880), Hewitt (1872), Hull (1877), Lock (1888), Sabonadière (1870), Rigaud (1896), and a manual issued by the Colonial Ministry in Brussels. Jotapen (1915) is superficial and contains many errors.

An attempt has also been made to issue a modern Handbook voor de Koffiecultuur, and two volumes have been published (1931 and 1933). Knaus' excellent treatise on curing and a well documented volume on pathology by Bally are among other recent works of importance. However, there has been no detailed review of the literature on many other subjects, for example, the numerous species and their hybrids available to the planter, methods of handling them, modern improvements in planting techniques, and so on. A short survey of some of the latter subjects was published by Cramer (1927, p. 135), and another more recent work treating several basically important questions is Huitema's study of the native coffee production in Sumatra (1935). Huitema's treatment of many problems is broader and more thorough than one might ordinarily expect in a production from a single locality, and it contains a good bibliography including many older publications rarely cited in more recent works. Huitemas' book gives an excellent, well documented summary of the history of the government plantings in the Netherlands Indies, and all the policy changes in their management.

From general literature on coffee in other languages a few books in English can be cited. One of the most recent, Uker's, "All About Coffee" (1935), is a good popular account, profusely illustrated, and it contains many historical notes on roasting the grains and preparing the beverages as well as a good deal of information on the trade. There are also chapters on certain scientific aspects of coffee such as those on the botany, chemistry, and pharmacology of coffee. A somewhat older book is Cheney's, Coffee (1925). It gives a description of the various species of *Coffea*, together with an economic and ethnological discussion of coffee, but it is very incomplete, containing almost no data on the present status of the planting industry in Indonesia. The development of Robusta production in Indonesia after the turn of our century is hardly mentioned; and the statement, "It first became known from the Rio Nuffes region", (Cheney, 1925, p. 92) is erroneous. Many other statements in the book have been criticized. In 1927 Ultee (1927, p. 36), in commenting on Cheney's chronological table for Indonesia, said that he seldom found so many errors in so few words. Hille Ris Lambers (1927, p. 339) indicated additional errors and omissions. Chevalier (1929, p. 96, 97, 107, 108), expressed doubts of some statements in the book. Grist's book on Malayan agriculture (1936, p. 188) gives a highly condensed but competent review of the techniques of coffee production. A complete description of coffee growing in Kenya was prepared by the staff on the Scott Agricultural Laboratories and the agricultural economist of the Kenya Department of Agriculture, and published with a contribution by the director of the British East African Meteorological Service under the editorship of McDonald (1937). This excellent book, one of the most up to date titles in coffee literature, gives few data on Robusta. It relates almost exclusively to Arabica, virtually the only species grown in Kenya.

There are several older as well as some more recent works in French. Henry Lecocq's book on coffee (1899) was an excellent and comprehensive description of planting techniques in that day, with many details on the species known at that time. He even discusses *C. canephora* Pierre (p. 32) with a note that Laurent (then a professor in the Agronomic Institute in Gembloux) considered it a species of the future for the Congo. This point reveals how modern the book was for its time. Pierrot's, Culture du Caféier (1906) was already antiquated when it was published. He said that grafting was not practical (p. 17), and the only species he mentions were *C. arabica* and *C. liberica*. A book by De Wildeman (1908) on several tropical crops also treats coffee in general. It is composed of some translations from foreign literature and contains a list of the species then known.

In 1908 Fauchère published a practical guide for coffee planting, a good description of the technique for its day. For instance, it contained a review of the various species then known, but it is now out of date, Fauchère's Guide Pratique contains a well written article on coffee growing (1922, p. 193), but it is also obsolete. A more recent book by Chevalier (1929) gives a good general description of the history of coffee and of the botanical and biological aspects.

Another modern book, edited by Martin (1938), is mainly devoted to Arabica. There are only a few lines on the other species, and they contain many errors. *C. liberica* is mentioned as being of interest in as much as its seeds are fairly homogeneous (p. 21). He says that *C. excelsa*, with very small seeds of varying size and shape, is not practical for cultivation (p. 21). Robusta, mentioned by the other authors as *C. canephora* var. *robusta*, is described as generally containing only one seed per fruit (p. 22). British Indian coffee is said not to have suffered generally from *Hemileia vastatrix* (p. 205). Another French book treating the technique of coffee production is by Sibert

(1938). I was able to consult only the second part of this work. It treats the curing of the product in comprehensive terms and also contains a bibliography.

Special mention should be made of the excellent general description of coffee cultivation and production in the volume on coffee in Sprecher von Bernegg's, *Tropische und Subtropische Weltwirtschaftspflanzen* (1934). It gives an excellent synthesis of data on coffee planting all over the world, with an extensive bibliography and a useful statistical table. It could hardly be expected to be correct in every detail, but its outstanding virtue is that the main facts are grouped together in a well balanced general review. It has been the best general description of the world's coffee planting industry available up to the present. However, there is still a need for a more detailed discussion of various aspects of the cultivation of coffee for the use of the practical planter. Many new problems have arisen since 1934, and several new trends have developed, not only in Java, but also in other countries.

PURPOSE OF THIS BOOK

One of the aims of the present volume is to help fill this gap. The writer considered publishing his notes as an abstract of the literature of coffee. The lack of such a work is a grave handicap to workers in this field. The only review of the literature that is available is old, and it is far from complete for the period it covers. Of the literature dating from the end of the nineteenth century, several books cited by de Haan (1923) have not been analysed, since they contain so little material of current interest, e. g. Boutilly's book (1900) on *C. liberica*. This information is available in a more original and a more complete form in the annual reports of s'Lands Plantentuin, which are abstracted in this study.

The Institut International d'Agriculture's list of literature on coffee constitutes the best current bibliography of non-Dutch publications on coffee. But Chevalier has properly complained of the scarcity of surveys of this field. Since information on coffee in other important producing countries is not available in Indonesia and even manuals are not available, this bibliography was a substantial help, but it could not satisfy all the deficiencies which must be attributed to the unavailability of literature, especially that of Dutch origin.

Bibliographical references in the present work have been made as full as possible, and the exact page reference as well as some other necessary information have been included. The words and ideas of the original authors have often been rearranged as a result of the difficulties encountered in handling such diverse sources, but my whole intention has simply been to make it easier for readers to reach their own conclusions.

There have been two main difficulties in writing this book. The first results from the effort to be complete and still hold the text to the minimum. There is so much valuable historical information that may be lost that it seems the part of wisdom not to be too niggardly in reviewing it. Thanks to Ottolander, some of it seemed so interesting to the research institutes that it was reprinted recently in *Bergcultures*. It was certainly worthy of reprinting, but other studies, such as Vogler's denial of degeneration in the case of Java coffee, Kramers' views on grafting, the history of the Kavisari and Kalimas hybrids, and the desire to introduce "new blood" into Liberian coffee are in danger of being forgotten. They should be preserved for the research worker as well as for the planter, who will find here a starting point for new ideas and new projects and perhaps, in some cases, will be spared unnecessary work. The same can be said of more recent developments. Describing and explaining them at some length may stimulate the planting industry to take advantage of the newer methods and thus help to develop them further.

The author's second difficulty results from the complexity of the subject. Frequently data on one aspect of a problem relate to other aspects, for example, data relative to the shade problem, to pest control, and to soil conservation. To avoid overlapping and repetition, the original texts have been revised to suit the syntheses in the present work, although the original author's ideas have been scrupulously respected. This difficulty is aggravated further by authors who employ special terminology in which terms with a generally accepted meaning are used in a different sense. The discussions of the various kinds of branchwood for grafting may serve as an example. Merely to copy the original text would be confusing, but the abstractor dared not wander too far from it. An effort has been made to set up a uniform framework for the synthesis which will be applicable to each chapter in order to maintain the equilibrium so important in a work of this sort. The writer has reproduced opinions from the abstracted literature as faithfully as possible.

We will note in the following pages a multitude of workers engaged in research on coffee, each working in his special problem. One tries to explain complicated problems with common sense. Another studies diseases and attempts to base their control on their biology. A third helps the breeder by seeking the logical foundation of the plant. A fourth was devoted his energies to looking for new and useful forms. I have here tried to contribute my own share by furnishing the synthesis, re-

porting observations and experiments, perhaps even the errors and lacunae. This will serve to obviate repetition in research and to point up those problems that need further study and development.

In view of the interest of Latin America on arabian coffee, some of the older literature on it and some newer papers on problems such as suitable shade trees have been abstracted at some length.

One of the aims, by no means the least important, in writing the present book was to make the experience and the research in Indonesia more accessible to the outside world and at the same time to bring some of the little known studies in other countries to the attention of Indonesian workers. The interchange of thought among the various coffee-growing countries does not seem to be sufficiently well established. If the present book helps to improve this situation somewhat, its author will feel properly rewarded for his work.

CHAPTER 2 EARLY HISTORY

Coffee as marketed by the planter consists of the dried seeds of the coffee plant, which, after roasting and grinding, can be extracted with water to make an agreeably flavored and stimulating beverage. The use of coffee dates from an early period in its country of origin, Abyssinia (Chevalier, 1929, p. 2). From Abyssinia coffee spread to the Arab world (Chevalier, 1929, p. 8), and in the seventeenth century it came to western Europe (Thurber, 1881, p. 55). The literature on its early history is cited in great detail by Watt (1908, p. 363), and an excellent short account of the early history may be found in Burkill's Dictionary (1935, p. 619).

Chevalier (1929, p. 14) has summarized the oldest literature on coffee in Europe, reproduced some old drawings of the plant, and described the development of its use in Europe. Italy was the first European country where coffee was appreciated, around 1630, and after 1660 the use of coffee spread rapidly among the citizens of Marseilles, but it was not until the nineteenth century that the use of coffee extended all over Europe. When the beverage became popular, its commercial possibilities were at once grasped by Dutch merchants, and the Dutch East India Company started to establish the coffee planting industry in Indonesia. The introduction of the first coffee plants there dates back to the end of the seventeenth and the beginning of the eighteenth century. The first plants were killed by an earthquake and the subsequent floods. About 1700 another effort was made to introduce the plant, and in 1706 some plants were sent to Holland (Kalff, 1927, p. 141). They were planted in a hothouse in the Hortus in Amsterdam, and from these all the Arabica in tropical America descends (van Stein Callenfels, 1916, p. 30). The Company was eager to extend production, because of the high European prices for the raw product. Arabian coffee was planted in the neighborhood of Weltevreden (Kalff, 1927, p. 141) and in west Java. In April 1711 the native regent of Tjiandjoer sold the first small lot of 102 pounds to the East India Company for f 50.⁴— per picul (van Stein Callenfels, 1916, p. 30).

In 1717 a shipment of 2,000 pounds was sent to Holland (Cramer, 1913, p. 4). In 1724 some 500 tons of coffee came on the market in Amsterdam, indicating that commercial coffee production was established. From 1724 to 1736 it is known that 2,000 tons of coffee were delivered annually to Holland, and after 1736 this amount was increased to 3,000 tons annually (Encycl. 2, 1918, p. 385). Statistics on the exports in this first period (1711-1794) may be found in van den Berg (1880).

Java was the first country where coffee growing was taken up by the European planter, but it did not remain the only one very long. The Dutch also introduced coffee into Surinam, in 1718 (de Candolle, 1883, p. 335). One of the coffee trees sent from Batavia in 1710 to the Botanical Garden of Amsterdam prospered there in a hothouse and produced fruit. For a report on this, see the original letter of Nicolas Witsen, quoted by Cramer (1913, p. 4). Some of the young seedlings obtained from this tree were taken to Surinam. According to de Candolle, in 1725, the governor of the neighboring French colony, Cayenne, obtained some plants or seeds secretly during a visit in Surinam and propagated them (de Candolle 1883, p. 335). It is said that the Jardin Botanique de Paris surreptitiously procured a cutting from the Amsterdam garden and raised a vigorous tree from it. A slip from this tree was entrusted to a French naval officer, Gabriel Mathieu de Clieu, for introduction into the West Indies, and he is reported to have shared his daily ration of water with the young plant throughout the unusually long and stormy voyage. The slip reached Martinique safely in 1720, or 1723 (Ukers, 1935, p. 6), and it became the parent of an immense progeny. Its descendants not only filled the fields of Martinique and Guadeloupe, but in a few years they had found their way to Jamaica, Puerto Rico, Haiti, Cuba, the lesser Antilles and Central America, the Guianas, and Brasil. The plant from the greenhouse in the Amsterdam Botanical Garden seems to have been the mother tree from which most of the plantings of Arabica in the world descend. James Douglas, (Chevalier, 1929, p. 32), has therefore called the Amsterdam Botanical Garden the universal nursery of coffee.

The Hortus Academicus in Leiden also claims a share in the spread of the coffee tree in the older period. The Uffenbach brothers visited the Garden in 1711, and mentioned "a young coffee plant". This may have been the same plant that the Amsterdam Burgomaster Pancras brought to Louis XIV after the Peace of Utrecht in 1714. The first hothouse in France was built at the Jardin du Roi to house it. It is said (Veendorp & Baas Becking, 1938, p. 111) to have become the mother plant for the French Antillean coffee plantations. No evidence is submitted for this, however, and it seems likely that coffee spread first from Holland to foreign countries through the Amsterdam Garden.

According to another story, Brasil acquired its first coffee plant in 1722 from Cayenne via Pará on the Amazon. The cultivation spread to the neighboring state of Maranhão. In 1774 two small

⁴ The symbol f stands for Dutch guilders.

trees from Maranhão were taken to Rio de Janeiro and planted in a private garden. The trees prospered and subsequently an enterprising Belgian named Moke started a regular coffee plantation in the midst of the great fields of sugar cane and cereals which then constituted the chief source of the wealth of the province (Thurber, loc. cit., p. 124). Then coffee planting spread to other parts of the world. In 1717 coffee plants were introduced from Mocha in Arabia into the island of Bourbon (Réunion), and the following year the Compagnie Française des Colonies sent plants to the same island (de Candolle, loc. cit.).

In the twentieth century coffee production increased enormously, especially in South America. At present Brazil is the principal coffee-producing country; Colombia comes second, and Indonesia is now the largest producer in the eastern hemisphere.

It is not possible to predict the future development of coffee production. Coffee has held its position so well that no considerable reduction in world consumption seems probable. The prophecy of Madame de Sévigné, "Racine passera comme le café" (Fauchère, 1922, p. 194), has not come to pass. In passing it might be noted that Chevalier (1929 p. 24) says that Coubard denied this tale, and Ukers (1935, p. 87), quoting Larousse, also rejects it.

BOTANICAL DATA

The species of coffee first introduced into tropical agriculture in the various colonies was *C. arabica* L. which was the only kind planted for over a century and a half. It grows as a shrub or small tree with glossy leaves and thin, flexible branches. Other species, introduced later, have thicker and stiffer branches and larger leaves. In all species of coffee the white, fragrant flowers appear in the axils of the leaves. From 7 to 12 months later the fruits ("berries") ripen. They contain two seeds known as the coffee "beans", enclosed in a hard "parchment skin" with a furrow on the flat side where the seeds touch one another.

A note should be inserted at this point on a controversy about the endosperm formation. A curious bit of evidence for the presence of a real endosperm has been brought forward recently by Krug and Carvalho (1939, p. 515), who, after an exhaustive review of the literature on the subject, stated that a mutant of *C. arabica* had been found. It was called variety Céra, and differed from the normal type, that had grey green seed, by having yellow seed. The whole nutritive tissue of the mature Céra seed is yellow instead of green. It was found that plants grown from these yellow Céra seed also produced yellow when selfed. When flowers of these plants were pollinated with pollen from the green-seeded normal type, they always produced green hybrid seed identical in color with the normal type. But if the variety Céra plants were pollinated with pollen of *C. excelsa* and *C. liberica*, both of which have yellow color, yellow seed were always obtained. From these facts it may be concluded that the bulk of the mature coffee seed is formed by real endosperm.

In the ripe berry the outer skin and the slimy layer under it, the "pulp" or "glucose" layer, represent the pericarp, and the "parchment skin", represents the endocarp. Within the latter the bean is surrounded by the "silverskin" or the remnants of the integument. The bulk of the bean consists of the folded endosperm, in the middle of which there is a figgure. The "silverskin" is generally green when fresh, since it contains some chlorophyll. The endosperm is homogenous and consists of cells containing fat in their protoplasm and chlorogenic acid dissolved in the liquid of the central vacuole, but no starch or tannin (Roelofsen, 1939c, p. 158).

The seed of most species contain caffeine, an alkaloid with stimulative properties. The percentage of caffeine calculated on dry weight in the seed of various species may vary a good deal. The seed of some species, mainly from Madagascar and nearby islands, contain no caffeine at all (Chevalier, 1938).

The species with seed containing caffeine also have small quantities of the alkaloid in other parts such as leaves, twigs, etc. The data have been collected by Kamerling (1918, p. 218).

Herndlhofer (1933, p. 279) analyzed parts of young and old coffee trees for caffeine content and obtained the following results:

Table 1. Caffeine Content in Percentage of Dry Weight

| | Three-Year- Old Tree | Thirty-Year- Old Tree | Sixty-Year- Old Tree |
|-----------|-------------------------|--------------------------|-------------------------|
| Leaves | 0.31 | 0.191 | 0.150 |
| Twigs | 0.04 | 0.017 | 0.013 |
| Stem | 0.01 | 0.026 | 0.027* |
| Main Root | 0.01 | 0.020 | 0.047* |

* Wood

Monthly analyses of leaves, twigs, etc. were also made; and the figures for these analyses and a description of the methods used are contained in the article.

About 60 species of coffee are known, and most of them are native to Africa. A few unusual species are indigenous in east Asia and some in Indonesia (Koorders, 1899, p. 493); among which is Coffea horsfieldiana Miq., which is sometimes sold as an ornamental shrub in Malang. According to Koorders, this kind is identical with C. bengalensis Roxb., which he found in Java only as a cultivated plant (Koorders, 1899, p. 494). Another species in the same group, C. madurensis T. et B., is indigenous in Madura and is also found in the Watangan mountains near Poeger.

The oldest and best known species of the genus, C. arabica L., is indigenous on the high mountain slopes of southwestern Abyssinia. It is said to have received its common name from the Kaffa province. From there the plant came to Arabia, and it was from this country that it was introduced into Java (Cramer, 1913, p. 4), where it was the only cultivated species until the last quarter of the nineteenth century.

Although the prosperity of the planting in former centuries has proved how suitable the soil, and climate of Java were for C. arabica and although animals, the loewak or coffee rat, Paradoxurus hermaphroditus, which eats the ripe berries, must have spread the seed, Arabian coffee does not seem to have established itself in the spontaneous vegetation of Java, except perhaps in one place on Mt. Sindoro (Koorders, 1899, p. 491).

De Candolle notes (1883, p. 333) that in Brazil and the West Indies the seed of C. arabica often germinate near the planted areas and naturalize the species. From this fact he concludes that if it is found wild in Guinea and Mozambique, the species may also have become "naturalized" there in consequence of cultivation. This does not seem to have taken place in Java, although here, too, some escaped plants may be found in the neighborhood of the plantings.

GOVERNMENT PLANTINGS IN INDONESIA

Coffee growing in Indonesia started as a free enterprise, but between 1725 and 1729 the East India Company established a monopoly. Production was restricted, and the policy of cutting out plantings in order to prevent overproduction was applied in 1733. The company fixed the quantity that could be exported to Holland. During the decade 1711-1720 there was a total export of only 815 piculs, but it increased to 184,063 for 1721-1730 (Thurber, 1881, p. 71).

Toward the end of the eighteenth century the extirpation policy was gradually abandoned and the surplus sold in Indonesia. Daendels favored extending production and made rules for compulsory growing and deliver. Raffles retained this system only for the Preanger province. Afterwards a system of renting the plantings to natives was introduced, but production was free in appearance only.

Coffee assumed primary importance in the national economy of Indonesia when it was planted under the "Cultuurstelsel" after 1830. In this, the native in many districts was obliged to plant a certain number of coffee trees every year, to cultivate them, to harvest the crop, and to cure the product, which then had to be sold to the government at a fixed price that was much lower than the market price. Production increased rapidly from 336,000 piculs in 1833 to over a million piculs in 1851 (Thurber, 1881, p. 7). From 1850 to 1880, when annual crops of nearly one million piculs were produced, these government coffee plantings brought in profits of millions, sometimes tens of millions annually, but they also put guilders in the hands of the natives and thus increased their buying power. Under favorable conditions the income from coffee per family could average more than f 300.00 per annum; but generally the figure was very low, and in the last 15 years of the government plantings the native received next to nothing for his crop (Encyclopedies van Nederlandsch-Indie, 1918, p. 398-399). Even in the eighties the return to the native from government coffee plantings was very low (Jaarveslag Soekaboemische, 1892, p. 27). Toward the end of the nineteenth century coffee production suffered a decline. The competition of new producers, notably Brazil, brought market prices down. The "coffee crisis" set in, the outlook was far from hopeful (Kramers, 1900, p. 36-37). In the same period the planting industry of the Orient was threatened by a serious leaf disease caused by a fungus belonging to the rusts, named Hemileia vastatrix B. & Br., which attacked the tissue of the leaf and formed orange-yellow spore patches on its underside. A great deal of work was devoted to finding a remedy (Burck, 1887 and 1889), but no effective method of combating the disease could be found. From about 1885 on the yields decreased, and after a long period of decline, government planting came to an end in 1919 (Gouvernements, Koffiecultuur, 1888 and 1889).

This continuous regression was due to a combination of causes. The leaf disease reduced the crops in many regions to such an extent that the native planter did not receive an adequate reward for his labor. The technical measures prescribed for treating the disease were not always practical, and sometimes they were even ruinous (Burck, 1896a, p. 383). The government committee which investigated the causes of the deterioration of government plantings in 1888 concluded (Kamerling, 1914, p. 9) that the increasing lack of suitable land near the native villages was the principal cause of de-

clining production. A gradual abandonment of the less productive fields led to a reduction in the area under cultivation in the last period of the government plantings (Huitema, 1935). Plantations were frequently abandoned when still fairly young. From statistics on the annual plantings, Kumeman calculated that prior to about 1879 the average age of the regular government plantings was slightly over 10 years, and after that year it decreased continually until it was only 8 to 9 years in 1882/83 and only 6 to 7 years in 1885 (Kumeman, 1890, p. 9). It was found that C. arabica trees could attain an old age and remain productive under the conditions of native planting, and these conditions were by no means ideal. In Bali there were some very good plantings, generally well shaded by dadap. The fertility of these old trees was surprising, although there were always many trees among them which did not produce (Vink, 1929, p. 35).

The Dutch East Indies Forest Service often complained of the disastrous effects of wasteful clearing of virgin forest for the government coffee plantings. On Java, and on several of the other islands, forests which were important for regulating the water supply of the rivers used for irrigation were destroyed. In the old days the plantings were generally laid out on rich jungle soils covered by heavy forests. In later years these soils may have been scarcer. When old plantings were abandoned, the forest did not restore itself, and the area became a grass plain, sometimes occupying tens of thousands of hectares. The denudation of several of the mountain tops in Java which were originally covered by dense forest must be attributed to the coffee plantings (Altona, 1913, p. 303). When the coffee fields were abandoned, the native occupied the land with annual crops, but only temporarily, and when he left it, it became a grass plain. The history of many hill lands in Java may be summarized in the cycle of forest, government coffee plantings, extensive native plantings, but sometimes skipping this step, and finally grass (Ham, 1908, p. 154). Koorders (1894) described vividly the effect of the government coffee plantings and their abandonment on the land. In Ponorogo 70,000 hectares of forest were turned into grasslands in this way. When it was originally planted with coffee, this land regularly yielded 4,000 piculs per annum between the 10 years 1850-1860. By 1892 the small part that remained in cultivation yielded 40 piculs. In 1880 coffee was again planted in the best places, but it had to be abandoned.

PRIVATE PRODUCERS IN INDONESIA

In the latter days of government planting, beginning about 1885, a prosperous estate coffee industry developed in Java. After some years of prosperity the fall in market prices and the increasing virulence of leaf disease also brought about a decline here during the first decade of the twentieth century. However, the skill of the planters, the good management of intelligent business men, and the help of a special research division of the Department of Agriculture and of the research institutes for the industry combined to overcome this crisis. From the statistics on the crops it is clear that a revival occurred about 1919; and, in later years the coffee production of Indonesia became fairly stable. It was marketed by estates, which produced slightly more than half of the total annual crop of the country, mainly in Java, while the other half was produced by natives in southern, central, and northern Sumatra, in Bali, and in Celebes, (Ultee, 1934b, p. 345).

The progress of the industry rested essentially on the introduction of new species. As pointed out, in no other coffee-growing country were so many different kinds in production (Cramer, 1924a, p. 229). This is the safeguard for the future. There must be disease resistance, for that is what killed the old coffee of Java. With disease resistance there must also be good adaptability to growing conditions.

The original C. arabica or "Java coffee" is a rather tender shrub with capricious crops, greatly dependent on weather conditions. Other species introduced later are less sensitive in this respect, for they have several large flowerings with smaller ones in between, or they may flower the whole year round. Shortly after the introduction of C. liberica this characteristic was recognized as a safeguard against crop failures (Prins, 1895, p. 617). Data on the first flowers and the ripening of the fruit of C. liberica as it occurs during the year, may be found in Verslag (1877, p. 27; 1878, p. 22).

The greatest stimulus to the revival of the industry after its complete failure from leaf disease, was the greater resistance to leaf disease offered by the newly introduced Robusta plants and allied forms. When they had their first considerable crop about 1905, they also gave planters new hope for the future (Cramer, 1909a and 1910b).

RESEARCH

Three groups contributed to the revival of the coffee industry and to its subsequent progress. The improvement of the technique of coffee planting must be credited, for the most part, to able planters who devoted themselves to the development of their industry. Men such as Ottolander, van Riemsdijk, Butin Schaap, Everard, and van Lennep will be remembered for their work in improving the

technique and introducing better material, and for their efforts at propagandising better methods and better materials among their fellow planters. Financiers interested in the crop also contributed their share to its progress. Outstanding among this group were D. Birnie, H. s'Jacob, and J. J. Benjamin. Working in collaboration with these two groups, botanists and other scientists made great contributions to the development of the coffee industry. Organized research in coffee began simultaneously with the improvement of the technique of planting. At that time the scientist worked under conditions less favorable than those of the present day, a fact that appears from some amusing details in Berkhout (1940, p. 46).

In the days of the first appearance of *Hemileia* and of the introduction of *Liberica* coffee, the s'Lands Plantentuin was the only institute for scientific research in Indonesia. One of its specialists, W. Burck, was put in charge of work on coffee. After his important work on *Hemileia* he became scientific adviser to the government coffee planting service in 1893. From its beginning in 1876 (Treib, 1892, p. 49) the Cultuurtuin was intended for plant introduction and experimentation (Cramer, 1942, p. 134), and a collection of species and varieties of coffee was available there. In 1894 Burck proposed to the government the establishment of an experiment station suitable for both *C. arabica* and *C. liberica*, with enough land for crops sufficient to produce the seed required for the government plantings and to carry the expenses of the field work and management of the experimental tract. This would make it possible to do research on hybridization and soil improvement, on combating diseases, and on the shade problem. This plan was not accepted, but some years later Treub succeeded in obtaining such a station for the Botanical Gardens (Huitema, 1935, p. 34). While on leave in Holland in 1895 Treub (Verslag, 1896, p. 102) paved the way for the establishment of an institute for coffee research attached to the Botanical Garden at the s'Lands Plantentuin, in Buitenzorg. Operating costs were to be borne by the coffee producers while the Botanical Garden would collaborate in every way and pay for the building. The plan was realized in 1896, and by the end of November the installation of the laboratories was completed.

As a matter of fact, the government was at that time by far the largest coffee planter, and it is not surprising that a special division for studying the coffee planting industry was organized when s'Lands Plantentuin was expanded into a regular research institute. Its able chief, J. G. Kramers, had been successful as director of the Sugar Research Institute in Paseroean. There he had obtained good results from regular manuring of the cane fields; but when he tried to do the same with coffee, he found that manuring old coffee fields brought little or no improvement. Little progress has been made along this line even yet. Kramers' successive reports after visits to estates still constitute a reliable source of information about the situation at the time. The botanist of the new division, A. Zimmermann, did excellent work on diseases and pests, and his work on nematodes has been justly praised by Bally (1931a, p. 29). After several changes in the staff the special coffee division came to an end in 1911. Part of the work was continued by a special bureau for the introduction and breeding of permanent crops, which also included the Cultuurtuin and Bangelan.

About 1900 it was realized that more information was needed on technical efficiency in the Government coffee plantings. A special station, Bangelan, was established near Malang, the center of the coffee-growing industry. Its purpose was to operate experimental fields in which, under proper supervision, common practices in the coffee industry such as planting distance, shade trees, pruning, working the soil, and so on could be studied. The objectives of the new experiment station were explained by Kramers in a lecture to the planters (Kramers, 1901-1902, p. 546). The establishment of the Bangelan station did not provide full satisfaction to the planters, who wanted a trained official for research work (D., 1901, p. 61). When the decision was announced, planters expressed their regrets (Anon., 1901, p. 233).

In the first years the fields were largely planted with *C. arabica*, some *C. liberica*, and hybrids; but when the vital importance of *Robusta* and other new species was realized, Bangelan was used for testing them. It developed into a seed production station for new kinds of coffee (Cramer, 1916c, p. 392), delivering large quantities of seeds of various kinds to the planters. The importance of this kind of work at Bangelan was explained by van der Wolk (1912, p. 374); who urged that more funds be made available to the station.

The work on the introduction of new species of coffee was carried out largely in the periods 1905-1909 and 1914-1919. At that time Bangelan and the Economic Garden in Bogor served as multiplication stations for new coffee species and for preliminary testing of them. In recent years the value of this kind of research in general has been explained by Toxopeus, who gives as an example the work done in the Soviet Union, especially by Vavilov, in bringing together large collections of the wild forms of cultivated plants, mainly by sending expeditions to those parts of the world where they are indigenous. Toxopeus cites (1937, p. 71) from Hudson, "The breeder in the Soviet Union, when confronted with a new problem, avails himself of these collections and can rest assured that if the characters which he seeks exist, they are present in the material at his disposal; and if the

problem is capable of solution, he is therefore in a position to solve it" (Hudson, 1937, p. 289). In addition to maintaining a rich collection of various cultivated and wild species of coffee, Bangelan was used for experimental work. A large collection was made of small plots with grafts taken from superior or interesting trees among the new kinds. The possibility of testing new kinds by the cultivation of plots with seedlings raised from seeds taken separately from individual trees in the jungle (Cramer, 1910a, p. 468) could not be realized, since seeds taken in this way were never received. However, as soon as the new species fruited in Java, this principle was applied to those imported materials.

In this way Bangelan established a collection of the best representatives of many species of coffee. Later the station carried on extensive experiments to study the whole problem of coffee grafting. In this way it furthered the work of Cramer, who had explained (1935, p. 101) that his earlier work in Java, started in 1905, was based on two fundamental principles: first, that selection should be applied at the time when new species or other forms are introduced from the wild into tropical agriculture; and second, that vegetative multiplication should have a more important place in the technique of planting tropical crops. In 1916 a similar experimental tract which was not limited to a single crop, as at Bangelan, was set up in southern Sumatra.

The program for this new station, together with a scheme for planting it, was explained by Cramer (1914, p. 651). Soon after its start retrenchment limited its development, and, after a long period of uncertainty, it was sold in 1924 before it had been able to show results (Jaarboek, 1924, p. 24).

About the same time, in 1921, it was decided that Bangelan was to be sold or incorporated as a commercial firm with a capital stock valued at f 450,000, of which the government would receive two-thirds as payment for the estate. This was considered too high a valuation, and the transaction was delayed (A., 1924, 431). In the meanwhile Bangelan became a paying proposition, with an annual profit of about f 10,000, and the original proposal was not carried out. A writer, (Anon., 1931, p. 929), cited a few curious facts from the intimate history of this period, but he erred in confusing Kramers and Cramer, both of whom were associated with Bangelan. In 1928, a year in which a profit of nearly f 162,000 was realized (Jaarboek, 1928, p. 68), proposals for selling it were revived; and when it was found to be highly profitable, it was incorporated into the Government Estates, an organization already operating rubber, guttapercha, and palm oil estates on a commercial basis.

When this service took over Bangelan, the experimental work was continued. The fields planted in former years with individual seedling offspring and clones of *C. robusta*, *C. excelsa*, and other species of coffee, and with hybrids of such as *C. liberica*, *C. arabica* and *C. congesta*, were maintained, and Ferwerda published the results of this work. Save for this work, research for the private planting industry was left by the government to private coffee research institutes. The government only looked after the interest of the native coffee planters, who produced more than half of Indonesia's total coffee crop.

A good description of the methods of the research stations in Java, especially Buitenzorg, is given by Mendiola (1928-1929, p. 5).

The private research institutes developed an extensive organization after a somewhat turbulent early history. In 1905 the Cacao Research Institute under Zehntner, located in central Java and entirely supported by planters, was expanded into a general institute, thus including coffee. The history of the General Research Institute was well described by Ultee (1931a, p. 38). Zehntner left Java in 1906, and the institute experienced several difficult years. Financial uncertainty and other problems led to reorganization. In 1911 part of it was set up at Malang from 1911 to 1922 as a special research institute under the direction of Wurth. Research on rubber as well as coffee was conducted there. Soember Asin served as its experiment and plant-breeding station. In 1911 central Java acquired its own research where Roepeke continued Zehntner's work and van Hall started coffee selection.

In 1911 a research institute for the coffee, rubber, and tobacco industries in Besuki was started in Djember under the direction of Ultee. Its field station, Kaliwinning, was opened in 1914 (Ultee, 1915, p. 4).

The broad lines of research remained unchanged. A detailed description of the various institutes, their fields of activity, and staff organization was published by Cramer (1926). An excellent and concise report bringing out very well the essential aspects of the work of the research institutes and the cooperation between them and the planters was published by Coleman (1931). The reader senses at once that the Coleman report was written by an insider, and he did not hesitate to list the weaknesses of the research projects and to make fair and justifiable criticisms.

The situation at the end of World War II showed only a few modifications. The Malang Institute absorbed the institute in central Java; and the sphere of influence of the Besuki Institute became central and east Java, for which area it conducted studies of rubber, coffee, and cacao. The Besuki

Institute continued its work along the original lines, and special mention must be made of its special concern for Arabica. All these private institutes were financed by the industry itself, which was organized into a central Research Institute Association, to which all estates contributed by law. This Association published two serials, the *Archief voor de Koffiecultuur*, which contains extensive studies and results of original research, and the *Bergcultures*, a weekly publication containing shorter articles on current problems, lectures to planters, conferences, and similar materials.

CHAPTER 3
INTRODUCTION OF NEW SPECIES

COFFEA LIBERICA

In 1875 Coffea liberica Hiern was introduced from Africa to Indonesia by the Botanical Garden in Buitenzorg. It is a species characterized by vigorous growth, large, leathery leaves, and heavy berries and beans. In 1874 the introduction of seed from the London nursery of William Bull was tried without success; but in 1875 a member of the staff of the Buitenzorg Garden received from the S. S. Conrad in the roads of Batavia two Wardian cases with 118 plants, introduced from Liberia by way of the Hortus in Leiden (Wigman, 1890, p. 261). These plants arrived at Bogor in October 1875 and were planted in the Economics Garden in February 1876 (Morren, 1894, p. 4). The first flowers appeared in the beginning of 1877, the first ripe fruit in 1878.

There may have been an earlier successful introduction, with the help of a Rotterdam merchant, Hendrik Muller Szn. Morren (loc. cit., p. 5) cites a letter dated 14 November 1875 from Binnendijl, formerly hortulanus of the Botanical Garden, which states that there were then 22 plants of C. liberica in the Botanical Garden and that they had been received from the Kew Gardens. The shipment of some plants from Kew to Java in a Wardian case in 1872 or 1873 is also recorded in a report from a British Colony (Morris, 1881, p. 2). The offspring of the trees in the Economic Garden were distributed all over Java, and additional material introduced directly from London by private planters. The director of the gardens, R. H. C. C. Scheffer, thought the new species "wholly suitable for the climate" (Verslag s'Lands Plantentuin te Buitenzorg 1878, p. 29).

From the beginning there was a keen desire among the planters to start experimental plantings with the new species. The first seeds produced in the Economic Garden were sold at public auction for almost their weight in gold. A fruit containing two seeds fetched five guilders (Wigman, 1888, p. 8). This is higher than the prices obtained for the first plants. In the beginning Bull sold his plants at fifty guineas per hundred, "small things but hardy, 10s 6d each". In Ceylon in 1877 plants were sold at R 500* for 1,000 plants (Ceylon Observer, 1878, p. 142).

Liberian coffee soon became popular in Java, and its area of cultivation extended rapidly (van Romburgh and Wigman, 1896, p. 509), especially in the lower regions, where it adapted itself readily. It seems to have been comparatively free from leaf disease in the first decade after its introduction, although in 1881, shortly after Hemileia was discovered in Java, traces of the disease were found on some of the imported trees. In a period of about 30 years the fungus adapted itself to the newcomer, and the existence of Liberica was threatened.

COFFEA ROBUSTA**

In 1900 Coffea robusta Linden was imported into Java. The first mention of this species occurs in a catalog of L'Horticole Coloniale, a copy of which is in the library of the Malang Research Institute. In this catalog van Gorkum (1901, p. 568) recommended to his friends an experiment with Robusta and cited a letter from Linden, the director of L'Horticole Coloniale, in which Robusta was recommended for its great hardiness, its vigorous growth, its high yield, and most of all its great resistance to all coffee disease. He remarked somewhat skeptically that C. liberica was also praised when first introduced, but he felt it would be an irresponsible act to refuse a serious experiment with a new kind. His recommendation was not followed by action in Java. However, the same idea occurred to a visitor to the nursery firm in Brussels, and the first plants were sent to Java, to Soember Agoeng Estate, by Rauws, secretary of the board of directors, who saw specimens of it in the hothouse of L'Horticole Coloniale. This firm had received them from their agent, Ed. Luja, who was exploring the Belgian Congo (Nederlandsch-Encyclopaedie, 1932, p. 812). The species seemed to be common in the Eala district, where its value was not known to the natives (information from De Wildeman, cited by van Hall, 1912, p. 622). In the original description in Linden's catalog no details are given about the origin of the seeds planted in his hothouses. The catalog only states that, according to the agent, this coffee species was frequently found on the banks of the rivers and in the nearby jungle (Horticole Coloniale, n. d., probably 1900, p. 66).

A note by Chevalier on a book by Lepiae (Chevalier, 1937, p. 67) gives a somewhat different story about the origin of C. robusta. This note states that Laurent discovered the famous C. laurentii De Wildeman, identical with the plant we know as C. robusta Linden. He found it near Lusambo, on the banks of the Sanikuru, and it was said to be abundant on the left bank of the Lomani. The Arabs cultivated it on a small scale, and a colonist had planted 500 trees. All the coffee trees cultivated under the name of Robusta, in the various parts of the world (Chevalier, 1937, p. 67) are

* Rupees

** See footnote on Page 1.

originally from this small planting. Leploe (1936, p. 10) describes this small plantation of Robusta, mixed with Liberica, near Lusambo, the property of M. Gillain. It was from this plantation that Luja, an agent of the horticulturist Linden, brought seed to Linden in Belgium in 1899. Thousands of small plants, raised in pots in the hothouses of the Linden firm, were offered to planters in foreign countries under the name of C. robusta, a name well chosen for describing the vigor and fertility of the new species. Rauws sent a few hundred of them to Java (Leploe, 1936, p. 17). It should be noted, incidentally, that Leploe gives the name of the agent as "Lusa", but De Wildeman (1903, p. 29) writes the name as "Luja" and gives several details about this explorer, who returned to Belgium in September 1899. De Wildeman reports that C. laurentii De Wild., obtained from the banks of the Sankuru, was cultivated in 1895 at Lusambo. Apparently this relates to the same plantation. Plants of this C. laurentii were distributed to botanical gardens, but those in Paris apparently were not the typical laurentii, and thus there has perhaps been some confusion (De Wildeman, 1903, p. 56).

According to a report (Bally, 1926, p. 159) by Bally dated 15 November 1900, the first imported Robusta plants on the Soember Agoeng Estate looked weak, but a few months later the manager, van Baak, reported that they were doing well. It is curious to read how enthusiastic Rauws was about the plants he saw in Brussels, according to his letter of 19 June 1900. A hundred and fifty plants were ordered immediately at two francs per plant and sent to Java, where they were distributed to the estates on Soember Agoeng, Wringin Anom and Kali Bakar (Ultee, 1934a, p. 190). Some of the original plants were still alive in 1934; and Celosse (1934a, p. 952) published a note with a photograph of one of them on the estate, Soember Agoeng, which after more than 30 years showed no sign of deterioration and was still flowering profusely. After this first introduction several other estates introduced the species directly from Brussels, for instance, Soember Pandan, Bajoe Lor, and Kali Sepandjang (Ultee, 1927a, p. 1034), and in 1901 Soember Kerto acquired fifty plants (van Hall, 1912, p. 642). Chevalier mentions (1929, p. 87) that seed of Robusta such as those sold by L'Horticole Coloniale were sent to Java by the French horticultural firm of Godegroy-Leboeuf, but there is no mention of this source elsewhere.

The government acquired 24 plants from L'Horticole Coloniale and put them out at Bangelan in 1901, and the Cultuurtuin received some in 1903 (Buitenzorg Vers. 1904, p. 71). When the newly introduced plants started to fruit in the various places where they were planted, they proved to be early and high yielders. In a few years Robusta was recommended by research workers as well as by practical planters, among whom H. H. T. van Lemnep (1907, p. 683) assumed a leading position with his lecture on Robusta at the Coffee Conference in Soerabaja. Producers put more and more confidence in the new species. Funds were made available for replacing Arabica with Robusta, and new estates were opened in the jungle for planting.

Soon the future of coffee in Java could be viewed more hopefully (Cramer, 1909b, p. 8). Shortly afterwards Cramer, lecturing in Holland, could announce a revival in coffee production. The rapidly increasing production of Robusta by the Java estates—about 650 tons in 1909, 25,000 tons in 1915, 44,500 tons in 1916 showed that he had not exaggerated. Since then, the bulk of the coffee crop of Indonesia has consisted of Robusta.

OTHER SPECIES

After the value of Robusta had been discovered, a great deal of attention was devoted to the introduction of other new species. Between 1905 and 1909 the Coffee Division of the newly instituted Department of Agriculture explored the old gardens belonging to it and found several interesting and promising species awaiting study in the collections. In the Cultuurtuin a variety from Abeokuta introduced in 1898 and later named C. abeokutae Cramer (1913, p. 395) attracted attention (Cramer, 1908, p. 307), as did C. stenophylla G. Don, which was introduced in 1896 as a single plant from Kew (van Rosburgh, 1901, p. 608) and in 1899 plants were received from the Botanical Gardens at Singapore (ibid.), and which was represented further by a small planting in 1908 (Cramer, 1908, p. 308). Other interesting varieties were C. canephora Pierre, acquired in 1902 from the Kew Gardens (van Hall, 1912, p. 752), and another kind from the same group, native to Uganda and received in 1903 from Dar-es-Salaam (Cramer, 1908) which was named C. ugandae Cramer. Other introductions included C. congensis Froehner var. chilotii, introduced in 1903 from the Jardin Colonial in Nogent-sur-Marne (Cramer, 1909, p. 80); C. quillou, 1901, from the Jardin d'Essai, Libreville (Verslag, 1901, p. 119); and C. excelsa Aug. Chev., 1905, from Africa (Cramer, 1916a, p. 211). During the period from 1905 to 1910 new material of these older introduction was imported again. New species were also introduced by the Coffee Division. In 1907 plants of C. arnoldiana and of C. deuvevrei were obtained from the Serres coloniales in Laeken near Brussels. From the same source came some plants of C. canephora var. sankuruensis and C. laurentii, belonging to the group of C. robusta and probably identical with it, as well as C. canephora var. kwiluensis, entirely different from Quillou coffee and resembling the C. congensis hybrids later discovered at Bangelan. From the Jardin Colo-

nial in Nogent-sur-Marne came plants of C. dybowskii, originally obtained from Madagascar (Jaarboek, 1907, p. 184). In 1908 two plants of C. humilis Aug. Chev. were introduced from Nogent-sur-Marne.

In 1909 a totally different species C. schumanniana, was introduced from Amani (Jaarboek, 1909, p. 177). It has since been found that it did not correspond to the description of this species, but to belong to the genus Periploca, although it can be grafted with species of Coffea. In 1912 C. aruwimiensis was introduced from Paris (Jaarboek, 1911, p. 131); and in 1913 C. bukobensis, quite similar to C. ugandae, was introduced (Jaarboek, 1913, p. 39). Some data on these species and their offspring were published by van Hall & van Helten (1917) and also by the latter alone.

Most of all this new material was planted and tested in the Cultuurtuin and also at the station in east Java, Bangelan near Malang, which became a testing plot for the new species in 1905-1915. Another testing plot for the new kinds was established on Bajoe Kidoel Estate, east Java, in 1907 (Cramer, 1907, p. 732).

New introductions were also tested at Soember Asin, the seed production station of the Malang Institute. From den Doop, who was sent to Uganda to obtain parasites of the berry borer, the station received a kind of coffee said to be borer-resistant, and it was planted in 1925. Although the berries were attacked by the borer, the new introduction appeared to be of value as a uniform type, resembling C. ugandae, C. canephora, and even C. congensis, but not belonging to any one of these species. It was considered a new type, and was named for field 190 where it was grown (Hille Ris Lambers, 1931, p. 687). From this type clone SA.R.425 was developed.

The introduction of new kinds has continued. One of these introduced is the Kapakata coffee, first described by Hirschfeldt (1930, p. 851). The Handelsmuseum of the Colonial Institute in Amsterdam raised some plants of this species from seed received from Hirschfeldt in Angola and shipped them to Java in a Wardian case.

In 1938 two workers from Java, Hille Ris Lambers and R. van der Veen (1939, p. 819), made trips to Africa financed by the Coffee Fund to study cultivated and wild coffee there. As a result, various new forms of robustoid species and of Arabica and allied species were introduced by the Malang and Besuki Coffee Research Institutes. Among them C. eugenioides, the "Nandi" coffee of Kenya, closely allied to C. arabica. In a report on the trip, Hille Ris Lambers (1939a, p. 1805) describes the variability of C. eugenioides and mentions another species he observed, C. brevipes.

FURTHER WORK

The long list of new species imported into Indonesia since the introduction of C. liberica and C. robusta showed that material available for one of the most important methods of improving the industry. The arabian plantations were gradually disappearing. The great significance of introducing new species of coffee was fully realized by Treub (1910, p. 8) who based his optimistic opinion of 1909 that there was still a future for coffee in the country mainly on the success obtained with new kinds in the period from 1905 to 1909. Further development has shown that he was right. The large number of species introduced in the course of years does not mean that all available interesting material of the genus Coffea is now growing in Indonesia. In 1937 an interesting new species was discovered in Portuguese East Africa, C. salvatrix. It is resistant to Hemileia vastatrix and may be of interest for crossings. According to the description, it gives a product with a bitter taste and therefore is not commercially useful (Swynnerton & Philipson, 1936, p. 314). Several new species and varieties not yet introduced into tropical agriculture were described in 1939 by Chevalier (1939, p. 396). The reserve of the wild forms of coffee is certainly not yet exhausted, and there may still be surprises in store, since the interior of Africa is becoming more and more accessible and scientific exploration of it is progressing every year. It is in this connection that the specially valuable work done by the scientific institutes of the Belgian Congo may be mentioned. Coffee, like many of our tropical crops, is in a privileged position in that the planting industry is comparatively young, and the wild plants from which it originated still exist together with many closely allied forms. This fact enables us to go back to the jungle and to start selection at the moment it should begin, the moment when the wild plant is introduced into agriculture. At this time the occurrence of different types among the wild forms should be studied, and from the very beginning the various types should be kept separate so that the most valuable ones can be isolated as soon as possible (Cramer, 1910a, p. 468).

That further introductions were possible is shown by the fact that only a few species have been brought to Java from Madagascar, an island rich in species of different groups, as described by Chevalier. The caffeine-free coffees from Madagascar seem to vary in the wild state like the better known commercial kinds and to contain forms with both round and oblong berries (Dubard, 1906, p. 518). Thus the principle of keeping separate the seed from each seed-bearer in the wild should also be applied here. The Congo also still contains several valuable forms not yet represented in the collections in Indonesia.

In 1936, an ordinance was drawn up by which the export of planting material of coffee from Indonesia was prohibited. However, the director of economic affairs could allow export for scientific purposes or for other important reasons. This ordinance went into effect on 27 May 1936. The government of the Belgian Congo promptly passed a similar measure applicable to its territory, and thus it is now impossible to get material from there except in the special cases just mentioned.

The list of introductions of coffee already made suffices to show that a very rich backlog of species, varieties, and hybrids is represented in the collections of the Cultuurtuin and the research institutes. It would be difficult to find another tropical crop of which such a variety of forms is at the disposal of the planter. It is this rich material, which may be considered the most distinct advantage of the coffee industry of Indonesia and which is the best safeguard against trouble in the future (Cramer, 1907b, in Teysmannia), since it permits the selection of species and the breeding of hybrids for almost any set of conditions (Cramer, 1927, p. 135).

CHAPTER 4 TECHNIQUE OF PRODUCTION

SEED AND NURSERIES

The technique of planting became more complicated since leaf disease forced the planters to give more attention to their plantings, but many of the more primitive methods are still currently practised by the natives. A curious note on the technique of planting in 1805, by a Frenchman named Gautin, was published by van Stein Callenfels (1916, p. 52). An excellent and complete description of more recent date with notes on technique can be found in the *Vraagbaak voor de Koffiecultuur en Koffiebereiding 1941* (privately printed).

In Indonesia, new plants always have been raised in nurseries. In the old days selected plants from old fields were often used, and this method was advocated as the "natural" one (Ottolander, 1900/1901, p. 766). However, with improvement of growing techniques, which are following less and less the "natural" method, this method was completely abandoned on estates, since it did not permit proper selection of planting material, threatened to spread pests like nematodes, could produce undesirable plants, and plants with crooked roots. Nevertheless, even in the late nineties Kramers (1899, p. 79) mentioned the use of field plants by planters, who argued that the young plant itself was the best evidence for the quality of the seed from which it developed. Even some old government plantings near Poedjon, near Malang, had a reputation for their field plants. Kramers mentioned that there was a regular trade in them and remarked that plantings laid out with them looked all right. However, even then most planters preferred to use nursery seedlings for new plantings.

Coffee nurseries in Indonesia have always been shaded. The seeds are generally put out in the parchment skin, although according to Boom (1912, p. 1) young plants grew more rapidly when it was removed. Planters had a tendency to reject round beans for seed, since they were considered "abnormal" and believed to produce abnormal plants. Schweizer (1927, p. 249) found that seed from trees with abnormalities of the flowers showed a lower germinative energy, but that in the same tree round beans, normal beans, and beans from berries with three seeds did not show any differences in this respect, nor did the plants raised from them show any differences in appearance when a year and a half old. Later Gandrup (1935, p. 54) conducted further experiments with round beans and found no differences, thus confirming Schweizer's findings. Cramer (1913, p. 78 and 91) conducted experiments with beans of various kinds of coffee classed according to length, weight, and specific weight and found no influence on the germinative energy and only little influence on the further growth of the young plants. Schweizer (1927, p. 256) studied the germination of coffee seed classified according to various standards. Seed were taken from a planting of Robusta clone Bgn. 105, and the smallest beans that averaged 7.5 mm. in parchment skin as well as the largest, were planted. The small showed a greater germinative energy, but after two months, the stand of seedlings raised from them was very poor. They yielded only 40 per cent of plantable plants. Schweizer's conclusion was that very small beans should not be used as seed.

Often the seed are first put out in germination beds and later transplanted. The rootlets appear in 12-28 days. The cotyledons grow into the embryonal cavity and get their food out of the endosperm. The rootlet is pushed outside by the hypocotyl and is turned downward, while the little stem grows upward rapidly in a curve. Its end is still fixed in the earth by the cotyledons in the seed. Then it draws the cotyledons with the seed outside of the earth. The plant is now about 8 cm. high and assumes a green color. The cotyledons then free themselves from the remnants of the seed and are extended as broad, round, flat, dark green leaves (Froehner, 1898, p. 235). Plants in this stage are called "soldaatjes" (little soldiers). In about eight weeks later the first leaves are freed, and such plants are called "kepelans". Soon afterward the stem develops with successive pairs of normal leaves. The transplanting from germination beds to the nursery is generally done in the kepelan stage, but better results are obtained in the soldier stage. The plants in the nursery are planted close together, usually 15 cm. apart, but the distance may vary in accordance with the length of time the plants must be kept. Often the soil between the plants is covered with cut grass that should be chopped into a mulch to prevent damage to the young plants when they are removed.

The best age for transplantation has seemed to be after 6 to 8 months when the plants have about 6 pairs of leaves. This did not always necessarily fit in with the best time for transplanting into the field.

The late ripening of seed early forced the Java planter to order the necessary seed from Sumatra where the crop was more evenly distributed over the year. When Bangelan was being planned, Kramers (1901-1902, p. 559) foresaw over 50 years ago that it would be difficult to use it for the production of coffee seed for the Java estates since, under the conditions prevailing there, the crop would come in later than April and thus too late in the season. Kramers proved to be correct (Cramer, 1916c, p. 396). Generally the main harvest of coffee seed could be started in the middle

of the year, but some Robusta clones on Bangelan could be harvested much earlier (Cramer, 1927b, p. 1254). A curious system for producing ripe seeds early in the season was devised by van der Veen (1934a, p. 1087), who was successful in making unripe berries of Congusta red and ripe in 10 days by exposing them to the action of ethylene gas at a concentration of 1:1,000. The treated berries gave seed of which 40 per cent germinated after six weeks while only 6 per cent of the untreated ones germinated. Similar results were obtained from more extensive experiments with both Arabica and Robusta. The young seedlings from the treated berries developed into quite normal plants.

The storing of coffee seed in Indonesia required special measures for retaining their germinative power. In view of the danger of infection with Berry Borer, the seed was also made borer-free by treatment with turpentine vapours, a technique worked out by Begemann (1926, p. 208). The best medium for storing coffee seed proved to be moist charcoal. At Bangelan, experiments were conducted with it as early as 1913 with satisfactory results (Jaarverslag, 1913, p. 55 and 1914, p. 104). Ultee (1933b, p. 82) arrived at the following conclusions: In August all the seed producing gardens in Java should have had ample supplies, and the necessary quantity could be stored toward the end of August. The drying was not to be extended further than to reduce water content by 40 per cent. The seeds were then packed in gunny sacks kept in boxes lined with newspapers. On the bottom of the box a layer of at least 10 cm. of moist charcoal was spread (150 g. water per kg. charcoal). The space between the bag and the sides of the box was filled with the same moistened charcoal, the whole covered with it, and then covered. It was kept in a shaded place. Every month the charcoal needed to be moistened again with the same quantity of water used when the packing was done, and the seed well stirred. Every month a sample was taken and germinated. In this way seed would be kept until February or March. De Fluiter (1939, p. 1506) obtained good results by using one kg. charcoal and 150 g. water for 3 kg. of fresh coffee seed and storing in a concrete cellar with a stable, high humidity at 92 to 98 per cent, and a stable temperature of 25° - 26° C. when put into the cellar on 30 July 1937, the germination percentages on 28 January 1938 were still very high, 86 to 98 per cent for various Robusta clones except for Mb. 3.04, which gave only 78 per cent. A fortnight later the percentage decreased for several numbers, a condition probably caused by dropping of the moisture content of the seed before 28 per cent, which seemed to be just about the critical point. Arabica seed kept well for 10 months. Seed kept for only 2 to 3 months showed the quickest germination. The seed could be disinfected with turpentine vapours after being kept for six months without any bad effects.

From these data it was clear that if the seeds became available in a season not suitable for planting they could be kept for half a year without losing much of their germinative power. Another solution for the problem was to hold over plants in the nursery and to retard the growth by "couperen" or clipping or cutting part of the leaf (Vraagbaak, 1941, p. 47). When the seeds were available only in July or August, the plants raised from them in the same year were still too small for planting at the end of that year; and when they were held over for planting the end of the following year, they were too large. They could be kept back by clipping the leaves when the plants had three pairs of leaves. About two-thirds of the leaf was cut. The clipping was repeated with every new pair of leaves. As a result, shorter internodes were formed. The plants were of course, much smaller, and the stem part was in better harmony with the rootsystem by the time of the planting season.

The nurseries should be in condition for good root development and should have friable soil. Schweizer (1934, p. 168), who studied the method from a physiological point of view, gave some hints on its practical application and reproduced photographs of plantings established with clipped plants. In the field they were early closing between rows and showed strong resistance to drought.

In an experiment with clipping young seedlings, (Werkman, 1936, p. 351) the plants in the nursery were divided into three groups. In A, clipping was started when the plants measured 16 cm. in July 1934. In B, it was started when they were 32 cm. in December 1934. In C, they were untreated. The clipping consisted in cutting away from the limb all the leaves as they appeared. The nursery was kept under moderate shade. In November 1935 the plants were measured and weighed. The plants of A, averaged 44.7 cm.; of B, averaged 65.5 cm.; and of C, 156.5 cm. The number of internodes was about the same in each group. The girth corresponded to height, and so did the weights of the roots and of the stem and foliage. Treatment B seemed to produce the best results in the field.

TRANSPLANTING

Transplanting in Indonesia had been done generally with plants with a bare-root system or "tjaboetans". Sometimes a clump of earth was left on the plants called "poeterans", and stumps of plants more than a year old, spoken of as "overjarige stumps", were also used. It was advisable to have a good surplus of plants in the nurseries so that all stunted, yellow, or diseased plants could be eliminated, and with tjaboetans the plants with poorly developed roots also eliminated. Germinated seeds were never used as planting material directly into the field except as an extreme emer-

gency measure. An estate had to supply plants and often replant or make small extensions nearly every year.

Stumps were rarely planted. In an experiment at Bangelan (see Cramer, 1928, p. 16), however, it was found that this kind of planting material had many advantages. In this experiment the growth of 6 months old seedlings, planted as tjaboetans, was compared with that of seedlings of more than a year old planted as stumps with bare roots. Both groups belonged to the same seedling family, Robusta Bgn. 59.01. When the plants were a year and a half old from the date they were set out in the field: those planted as stumps were 30 per cent higher than those put out as tjaboetans, or bare roots. All plants from stumps had flower buds, and 14 per cent had already set fruit, while only 61 per cent of the plants put out as tjaboetans had flower buds, and only one per cent had a few fruits. An unexpected advantage of stump-planting was that not a single plant died after the transplanting, while 8 per cent of the tjaboetan plants were lost.

Schweizer, (1934, p. 168) studied stump planting from a physiological viewpoint and tried to determine the exhaustion and reformation of reserve food in the plant. Robusta kept the food reserves longer than Arabian; and when most of the reserve was used for forming the new shoot and roots, it began to form new reserves before the old ones were entirely exhausted. When the plants raised from seeds put out in August and September and stumped at the end of the next rainy season about 8 months later, it was found that a certain number, perhaps 20 to 30 per cent, showed a weaker growth. The nursery plants were exposed to the full light and therefore had a compact growth. About a month before the planting the leaves should be clipped. If the stumping is done shortly before the planting, there should be a thorough root pruning to stimulate the formation of fresh roots. Very good results have been obtained with stump planting. The only disadvantages in Indonesia were that the method was more expensive; more young plants were required as less thrifty ones were discarded; the nurseries needed to be kept longer and planting holes had to be made deeper.

PLANTING DISTANCE AND REPLANTING

The planting distance depends on the development of the adult tree and on external conditions. In Java, arabian coffee has the narrowest, and *C. excelsa* the broadest spread. For Arabian 2 x 2 m. or 8 x 9 feet (2.7 x 3 m.) is often used. For *C. excelsa* 4 x 4 m. is hardly sufficient. Robusta is put out at 2.5 x 2.5 or 3 x 3 m. There is a current notion among planters in favor of narrower planting of Robusta, in the belief that after the trees have entered the productive stage, the less desirable ones can be eliminated and still leave a sufficient number. A plantation of seedlings is composed of trees of very different bearing capacity so that it would be advantageous, if practical, to cut out the poor yielders and to replace them with better ones. As early as 1915, Anstead (1915, p. 1), in speaking of Arabica coffee plantings, directed attention to this point when he wrote, "It is the low jat trees which never bear a good crop, however favorable the conditions, which pull down the yield of the estate".

Later, among Robusta planters in Indonesia, instead of being thinned out, the poorest yielders were cut back and grafted with a clone which yielded well. Coolhaas (1941, p. 62), the director of the research institute in Malang, insisted that such grafting was routine work which should be done every year in order to maintain or increase the level of production. If old plantings had deteriorated too much, it might be preferable to practice integral field grafting by cutting all the trees down and grafting on the suckers, or by leaving the stems and providing them with a new, production robe by putting several branch grafts on them. The inconvenience of all these treatments was that the old planting distance had to be maintained. If it was thought necessary to change the lay out, there was only one solution: complete removal of the old trees and replanting of the reopened field according to more modern methods. Such a treatment was rather drastic, but it permitted correction of old errors. When, for instance, little attention had been given to the prevention of erosion in the lay out of the old planting, the land could be carefully terraced when it was reopened. At a Coffee Conference in 1934 in east Java, Gandrup made a plea for a periodic rejuvenation of old coffee planting. The difference is that formerly one kind was replaced by another kind. It is my belief that the newer clones promise very good yields. An estate should plan for regular replanting, dividing its area into a number of parts from which the same average number of plants is removed annually. The soil should be fallow for a year to protect it from nematodes before replanting. This process means four years without production.

The problem of the optimum planting distance was studied in experimental plots of Robusta. The systems compared were 2,070, 1,410, 1,015, and 705 trees per hectare. For the five years the plots with the largest number of trees yielded more than those which were more widely spaced. These last plots, with smallest numbers of trees gave only 52 per cent of the yield of the narrowly planted in terms of five year averages. However, it is of note that in the sixth year the more widely spaced plantings started to yield more than the narrow ones. Even in the first year of production

the trees in the wider planting gave a higher yield per tree than did the other plots. Although some experiments have been started on the utility of dense planting with a later selective thinning (de Haan, 1923c, p. 151) so far no clear information has been obtained on this point. It must not be forgotten that in old plantings there is a continuous thinning by the natural loss of trees and that it is compensated by continuous supplying or grafting on trees with a deteriorated stem. The result is that older and younger trees are mixed, and this situation is not unfavorable to productivity (Snoep & van der Veen, 1941, p. 180).

The question of the optimum planting distance was studied by de Ligt (1936a, p. 16) from another angle. He tried an avenue system, comparing 12 x 6 feet with 8 x 9 feet, and for six crop years, 1930 to 1935, he obtained an average of 17 q./ha. for the avenue planting and 14 q./ha. for the 8 x 9 plots. Every year the former yielded more than the latter. As a further development he conceived a belt system, with three dense rows at 6 feet, and then a greater distance between the densely planted belts at 12 feet. It was believed by Gandrup that this idea was good, especially for grafts, where the uniformity of the trees made selective thinning unnecessary.

TOPPING AND PRUNING

The trees in Indonesia are generally kept topped at 1 to 2½ meters. The height may vary with the trees in the same field. According to older workers, a greater height may be permitted for vigorous trees than for the weaker ones. Sometimes trees are kept with two stems, and one of these is then topped at a lower level. Suckers on the stem were regularly pruned, and the same was often done with the suckers called "wilde takken" on branches. Whenever a tree has been topped, the top of the stem has a tendency to develop new suckers. This can be prevented by removing the leaf with a sharp knife and also the surface tissue above it under the highest branches. It is from this tissue that the serial buds develop into shoots. If the serial buds are removed from the four highest nodes, the continuous shooting at the top of the stem is stopped. It was found that the wound soon heals (Waller, 1919, p. 1). In Java the topping of Robusta is done by cutting the stem just above a node and removing one branch with the same cut, called the Semeroe method, or both branches just under the top are removed called the Bangelan method, as described by Huitema (1935, p. 196). With Liberica coffees the customary topping of the trees stimulates the development of the branch suckers which exhaust the branch where they originate and should be pruned away (de Blij, 1907, p. 487). Their development may be prevented by a system of gradual topping, at first cutting the stem at 6 feet, and then putting a further story on it (Punter, 1908, p. 416). A similar system for building up the Arabian coffee tree, starting at a level of only one meter, was applied successfully in the Belgian Congo (P. T., 1937, p. 479).

In 1911 Wurth (p. 110) discussed the advantages and disadvantages of keeping Robusta topped at a low height. In the first place, in the lower coffee belt the stems of Robusta bend down when the tree is left untopped; but in the higher altitudes the stem remains straight, which makes picking very difficult. He observed that the subsequent inspection of the high tree tops was also nearly impossible, a disadvantage in view of possible diseases and pests. On the other hand, Wurth admitted that in the Banjuwangi region, where estates often left trees untopped, the yield was without doubt somewhat higher, at least in the first years. In the case of topped trees the production of fruit bearing branches might drop off and the yield with it. He noted further that with this same method, on 47 ten-year-old trees, that there had been no regression of yield. Wurth's conclusion was that for estates at an altitude of 300 m. or more, topping of Robusta was advisable. He recommended that two-to four-stemmed trees be retained, that they be topped at 7 to 8 ft., and that the stems which showed regression be removed. Wurth also referred to experiments at Soember Kerto estate and Bangelan on the problem. The various treatments (Jaarboek, 1913, p. 51) involved topping at 6, 7, 8, 10 and 12 ft. and also untopped trees, including both single-stem and multi-stemmed systems. The plots comprised 100 trees each, one set of Robusta, one set of *C. quillou*. The results over 4 cropping years were published in 1915 (Jaarboek, 1915, p. 67-68). For *C. quillou* the average annual yields were 12.81 q./ha. and 12.82 q./ha. for the lowest topping height. For the greater heights the yields were higher. For a topping height of 12 feet it was 23 q./ha. The single-stem and multi-stemmed systems did not show sharp differences. For Robusta the trees with low topping height gave an average of about 10 q./ha., the 12 foot trees gave 13 to 17 q./ha.; and the multi-stemmed trees gave 1 or 2 q./ha. more than the single-stemmed ones. In both cases the untopped trees gave nearly the same yield as the highest topped ones. In this experiment it was obvious that old Robusta bent over, when untopped, while the stems of Quillou remained straight. In working with Robusta, Ultee observed a topped single-stemmed planting that was compared with one of three-stemmed untopped tree. The former gave 11.6 q./ha. over a four year period, the untopped plots 13.8 q./ha. Various systems of topping and pruning were tried by Betrem (1938, p. 476), who could not find a correlation between the dying of branches and yield in Robusta. Trees on which half the number of primary branches were

pruned away gave the same crop as unpruned ones. Trees in a monoclonal planting kept on one stem gave the same yield as trees kept on two stems, although the latter trees bore many more branches.

At one time a system of permitting the stem of Robusta to grow through and bend was tried in some low lying fertile regions. The stem bent under the weight of the crop, and new shoots developed from the base. These were allowed to grow up, and generally each tree consisted of 3 or 4 stems. Every year the oldest one, more or less worn out, was cut and a new one allowed to grow up and take its place. The system applied in southern Sumatra by Kissing, the manager of Pasoemah Estate, and named for him, is somewhat similar. It was described and carefully explained by Kissing himself and by Rudin (1935, p. 1302). In it the crop came from primary branches on these stems. Since about 1934 the black branch borer has done too much harm to the primary branches, and planters have been forced to abandon this system. In two comparisons (Schweizer, 1933, p. 934) it gave more than trees kept on one stem and topped at 6 or 7 feet. The excess yields were 24 and 33.3 percent. In some instances the main stem became exhausted and developed no more vigorous shoots. As a way out a "candelabra" system was tried by keeping shoots on the stem and topping them. When the branch borer became disastrous to the crop, the stems were topped at $4\frac{1}{2}$ and $6\frac{1}{2}$ feet and afterwards grafted with branch grafts to give them a new productive "robe" (Isasca, 1941, p. 1366).

With Arabian coffee in Indonesia a somewhat similar system is followed, but here the tree is topped from the beginning and a strong "undertree" formed. The one shoot is allowed to develop, and generally it bears well. As soon as the "undertree" shows signs of exhaustion the shoot is cut away, and the undertree is allowed to recover and to develop a new shoot. It was claimed that more regular crops were obtained by this system (Vraagbaak, 1941, p. 91). A danger in this system was that sometimes the cutting away of the top was postponed too long, by which time it was again carrying a good many blossoms. The top should be removed as soon as the undertree starts to suffer, a circumstance that if neglected may reduce the crop of the whole tree (Kramers, 1899a, p. 82). Other systems of pruning popular for Arabian coffee in other countries such as the "Agobiada" method, which gave good results in Kenya (Stoffels, 1937, p. 14), have, as far as is known, not been tried in Indonesia. Various other systems of pruning applied in foreign countries have been summarized by Bally (1933, p. 162).

Sometimes it was desirable to "rejuvenate" a planting by stumping the old trees and allowing the stumps to form new shoots which could be shaped into a new and better tree. (This was not done because the trees were too old; as there have been no recorded cases of trees which have deteriorated from old age, in itself, as revealed in lack of growth or lack of resistance to disease. The real reason has been that mistakes were made in the beginning). Stumping of the trees appears to be cheaper than replanting the field with new material. This latter system also has advantages, for it allows more radical changes, but with stumping, the field becomes productive again at an earlier date. Experiments have shown that the best height for stumping was about $1\frac{1}{2}$ feet. It was expected that 90 percent of the trees would be shooting (see also de Stoppelaar, 1939, p. 1327) 6 months later, and of these about 20 percent would have to be replaced. Various means were used to prevent excessively rapid growth of the shoot, such as, root pruning by digging a circle around the tree, heavy pruning of the shade, or retaining several shoots in the beginning. If it was desired to use newer material, it could be grafted on to the shoots, for instance, for converting a planting of a less productive kind, such as Quillou, into a better yielding type like Robusta.

If the stumped trees were allowed to develop into new productive trees and no grafting was intended, the stumping needed to be done with consideration for the condition of the tree. Sometimes the lower branches can be kept, but stumping should never be under a height of 45 cm. from the top of the stem to the ground. It was found that it should not be done after the first rains had set in. The shoots should then be gradually thinned to one. Useful hints on the practical execution of this task were given in a lecture by de Stoppelaar (1934a, p. 972).

A somewhat similar system of rejuvenation consisted in a less drastic treatment, recommended for old plantings, by which the stem of the old tree was kept and the branches classified into worthless ones, which were removed, slightly better branches that were heavily pruned, and productive branches which were also pruned despite the fact that this pruning caused some loss of crop. The general condition of the planting needed to be put in order by an appropriate treatment of the shade and soil cover before the pruning. The tree was stimulated by the pruning to form a good many productive branches, mainly "fan" branches which restored the bearing power of the planting (Wilbrink, 1939, p. 933). In this discussion after de Stoppelaar's lecture (infra), Hille Ris Lambers recalled this system of pruning.

The secret of intelligent pruning is to cut where the tree itself shows the way. Many trees prune themselves quite well. The planting pruned by Wilbrink's system may be compared with a field in which branch wood of the same potentiality as the tree itself is grafted on each tree. Thus as many untested clones as there are trees are used, but this method presents a danger. It is better

to graft with tested and proven clones. Possibly Wilbrink's system may bring about improvement more quickly, but it may be questioned whether in the long run grafting with proven clones would not make for greater improvement. In Wilbrink's pruning system, nice looking fan branches may be obtained in the beginning, with a good initial production; but often these fan branches fail to bend, and it is by this bending that development of new branches near the center of the tree takes place.

Rudin (1936a, p. 465) discussed the rejuvenation of old Robusta trees by heavy pruning and the development of new stems from shoots. When the heavy pruning led to the new development of fruit-bearing wood on the old branches, there was the problem of whether this wood should be removed to permit the young stem to grow out above the old tree. When heavy pruning was necessary, new wood on old branches had to be cut away even at the sacrifice of part of the crop. This crop loss is not felt so keenly if only a part of the estate is pruned each year. In the various systems the regular pruning of the trees consists of cutting away branches or parts of branches. All dead wood and branches broken by disease are removed, a so-called purgative pruning.

Sometimes the ends of some primary branches were cut to force them to form new branches which caused them to ramify further and thus develop new fruit-bearing wood. A better system which served the same purpose was to cut some of the primary branches leaving only a few, perhaps two or three, internodes. The temporary reduction of the fruiting wood resulted in some loss of crop, but it prevented a drop in the yield later on by timely stimulation of the development of fruit bearing wood. The structure of the branches was sometimes also taken into account. If the shortening cut was made at the end of a set of short internodes, more branches formed than when the cut was made through a long internode. Excessively long frame branches were also shortened to bring the fruiting wood back nearer to the stem (Luchtmeier, 1940, p. 358). Hille Ris Lambers (1938a, p. 1277) stated that formerly the shortening of branches to 7 or 8 internodes had also been tried but gave unsatisfactory results.

In addition to this formative or constructive pruning in Robusta, there should be discussed periodic pruning in which the branches growing toward the stem end, and those that cluster too densely near the stem, are removed in order to open a space around the stem. This "Koker-pruning" so-called from the name of a planter, had already been known for a long time as "center pruning" in Ceylon. It consists in the removal of secondary branches near the stem, usually the two nearest ones. This pruning was not recommended on dry estates, but was advisable in a wet climate (Ultee, 1934, p. 868).

A planter described a case in which an estate yielded 12 q./ha. with regular centering "Koker-soei". When this pruning was stopped the yield fell to 5.5 q./ha., and as soon as centering was applied again the old average was restored (G.A.A., 1925, p. 21). Ottolander (1898, p. 422) was in favor of this system of pruning a half a century ago for *C. arabica*. With some new varieties with very dense branching some branches from the stem may be cut away here and there. This is a system intermediate between the "constructive" and "periodical" pruning (Vraagbaak, 1941, p. 93). The pruning of branch grafts demands special care, dependent on the branch wood from which the graft is made. It involves the reduction of the fan branches and the thinning of young fruit-bearing wood (de Stoppeelaar, 1939, p. 1330). A good review of the whole pruning problem was published by Gelinck (1942), who first described the development of the various branches along the same lines as those cited in the section on the choice of the grafting wood. The various objectives of the pruning were mentioned, and stress was laid on the desirability of starting the pruning early.

According to Hoedt (1932, p. 81) the best time to apply pruning to Robusta types was towards the end of the dry season when a maximum of reserve food may be expected to have accumulated in the tree. Thus there was a minimum loss from the pruning process. At that time the crop was generally finished, and the annual purgative pruning could be started. During the subsequent rainy season the Koker pruning, or centering, was done. In a region without a marked dry season it was more difficult to choose the proper time for pruning. In view of the labor supply available, pruning is generally done after the main crop is finished.

FERTILIZING AND LEAF COMPOSITION

Many experiments on fertilizing coffee have been made. In 1898-1904 experiments were started on many estates (Kramers, 1898), and the results were published in yearly progress reports. Another series of experiments, related to the treatment of the soil. The various artificial manures gave very small increases in yield (Kramers, 1901-1902, p. 552). The older experiments on fertilizing were reviewed by Ultee in 1927, and he mentioned the absence of noticeable results (Ultee, 1928, p. 85). In recent years this problem has been studied again. Dinger (1934, p. 631) explained the difficulties of these experiments and the long time they required, a fact which made them unpopular among planters. In old producing fields heavy applications gave such slight increases that fertilizing did not pay. With young coffee, especially in replantings, manuring with nitrogen had some ef-

fect. Phosphate was also needed on phosphate-deficient fields (Vraagbaak, 1941, p. 85). Raaf (1930, p. 842) reported favorable results from chemical fertilizers applied to young coffee plants.

The symptoms of deficiency and excess of various inorganic plant foods were studied in water cultures of *C. arabica* by s'Jacob (1938b, p. 1). Nitrogen deficiency resulted in very small plants, with yellowish green leaves, and the length of the root increased when the nitrogen concentration decreased. Calcium deficiency resulted in a severe root damage and a clog formation of the leaves, and the plants died early. Excess of calcium, given as CaCl_2 , did no harm, but with CaCO_3 the leaves became chlorotic. In this case the acidity of the nutrient solution decreased, diminishing the availability of iron. Lack of potassium was not readily noticeable since very small quantities of this element are sufficient for growth. When it was lacking small, grey, dry spots were formed on the edges of mature leaves. Excess of potassium caused marbled leaves of a light yellow color. The older leaves died earlier, and the roots were short and thick.

Neither deficiency nor excess of phosphorus had any effect. Apparently coffee needs only very small quantities of this element. Plants suffering from magnesium deficiency had very typically spotted leaves. Only a particular zone was spotted, and outside of this zone the leaves looked healthy, while inside they were slightly chlorotic. Excess of magnesium was very noxious. The plants were weak and slightly chlorotic, but there was no characteristic symptom.

Sulphur deficiency resulted in very small plants with yellowish convex leaves and small thin roots. An excess caused the same symptoms that resulted from too high a total concentration of the nutrient solution. With excess sodium chloride the margins of the leaves became reddish brown and dry. Leaves were very convex and hung down the stem. The sodium-ion appeared to be the culprit. Iron deficiency caused chlorosis with yellow leaves and light green veins.

In connection with the symptoms of deficiency of elements a few notes may be inserted here on normal composition of the leaves. Schweizer (1940a, p. 165) found that Ca and Mg increased until leaf-fall, independently of the crop, if the season was absolutely dry for at least three weeks before the samples were taken. Cuticular excretion played an important role in this increase. If the samples were taken during a rainy period, the amount of Ca and Mg decreased prior to leaf-fall. This influence of cuticular excretion was not found in young leaves.

In trees in bearing the P N and K contents of the adult leaves were maximum in the beginning. P and N decreased gradually towards leaf-fall, while K increased. During the development of the leaf there was a negative correlation between Ca and K. We must also consider the influence of the crop on the composition of the leaves. A large crop causes a serious die-back with Arabica, but it is somewhat smaller with Robusta. Schweizer showed that consumption of carbohydrates during the period when the fruit was turning red was enormous. This point will be discussed further.

Organic manure such as stable manure and compost was sometimes given to young plants in replantings or to supplies in older fields (Vraagbaak, 1941, p. 83-85). As early as 1896 van Romburgh (1896, p. 379) drew the attention of planters to the fertilizing value of coffee skins. He published the results of his analyses and suggested converting the skins into compost. An extensive arrangement for making compost out of coffee skins and stable manure was described by de Ligt (1937, p. 1740). The stable contained 25 pairs of oxen, and nearby were concrete compost floors or shallow tanks. The coffee skins were floated thence on water. They remained overnight in gutters, where the adhering water could drip off. All the dirt from the village, the ashes from the ovens of the drying house, and other refuse was added, and all this material was heaped up in the compost tanks to a height of about one meter. The heaps were turned every 3 weeks and kept for 2 to 3 months. The cost of the compost at that time was about 50 cents per cubic meter. From 26 to 30 cubic meters was applied per 1000 trees, and the cost per ha. was about f 19-21. The total area of the compost factory was about 1,200 square meters.

A simpler method of converting the fresh skins from a day's crop into compost was by putting them in a low, flat heap in a shaded place. If after 6 days the temperature had risen to 60°C ., the material was divided into 6 heaps. On the seventh day the first heap was kneaded together by treading on it, and the crop of the day was heaped on top of it. On the eighth day the next one was treated, and so on. In this way the skins of a day's harvest were always left 6 days as a loose heap like the first heap, and then trodden down, so that gradually a high heap was built up. The lowest layer contained 9.7 per cent moisture and 2.2 per cent nitrogen (Snoep, 1932c, p. 91-92). Fresh fruit skins could be used for spreading in the field but compost of coffee skins was preferable. One application of the compost could be put in the original planting hole. It increased the resistance of the young plant to drought and probably to nematodes (Snoep, 1933, p. 360).

In some experiments (Snoep, 1936, p. 918) with young fields, the results from organic manure were somewhat disappointing. In half of the cases organic manure combined with a chemical fertilizer had the best effect, and in the other half the effect was equal to or less than with chemical fertilizer alone. However, it may be, the manner of applying the organic manure could be improved.

The reddish brown soils of the Yang mountain were used for a series of compost experiments with coffees and rubber by van der Veen (1938, p. 217); and he found indications that for soils from estates at higher altitudes it was better to apply sulphate of ammonia and phosphate, while for the soils in lower altitudes sulphate of ammonia alone was sufficient. The results indicated further the danger of using too much fertilizer. He concluded that replanting should be preceded by a small experiment to ascertain optimum quantities of fertilizer.

The results of various experiments on the problem by the Malang Institute can be summarized as follows: An intensive manuring of replantings was very beneficial to the growth and first crop. When it was terminated after two or three years, it was found that the annual surplus over normal yield was less in the following years. It seemed possible that it could be maintained if fertilizing was continued, but it was unlikely that its continuance would be profitable.

A light dressing with nitrogen for transplants and replantings especially on the poorer parts of the fields, seemed to be justified. A heavier manuring was not recommended, since there was little likelihood of a considerable increase in the crop. Only in special cases, indicated by soil analysis, was heavier fertilizing with nitrogen and phosphorus advisable. In large replantings it was recommended as a good policy to lay out a test plot and, if in the first two years there was a reaction to certain fertilizers, they might be used on a large scale. If the results of the test remained favorable, the application would be continued. Although results of the use of organic manures collected in or outside the fields have been deceptive in the case of old plantings, still the use of all offal for the fields should be an objective without considering the actual results, since it is never possible to calculate the effect and since it is certain that the soil is improved.

It would appear that the application of cuttings of auxiliary plants like green manurers, makes manuring with nitrogen superfluous. Mulching must be considered only as shifting of nutriment if the auxiliary plants are not nitrogen binders. The need for fertilizing auxiliary plants has never been felt in east Java. It remains a curious fact that fertilizer seems to offer few advantages for a crop like coffee in which the deterioration of trees and the fluctuation from heavy yield shows that soil nutriment are often at a minimum (Snoep, 1941b, p. 1010). A detailed description of the manuring on an estate, in young plantings as well (Lencir, 1932, p. 1208) as in older fields, gave a good idea of how these methods were carried out in practice, especially in giving backward trees a certain quantity of stable manure.

The question of the chemical requirements of coffee were studied from a more theoretical viewpoint. Extensive experiments with water cultures of *C. arabica* were started by s'Jacob for studying its salt requirements and the pathological symptoms of malnutrition. They were continued by van der Veen (1940a, p. 199) with Robusta. Schweizer (1940a, p. 165) investigated the chemical composition of the leaf. Some years previously Schweizer (1936, p. 214) had directed attention to the connection between the composition of the sap and the presence of diseases and thought that future research should go in this direction.

UPKEEP

The upkeep of the plantings includes various treatments of the soil, mainly with a view to maintaining it in good condition for the development of the coffee roots, and protecting it from erosion and the loss of humus. Clean weeding is rarely done now except in young plantings. Some noxious weeds must be fought, above all Lalang-alang (*Imperata cylindrica*). Rudin (1935a, p. 346) found it could be removed by forking, but a better system was to exhaust the plant. At first it was cut as low as possible, and the leaves thus cut spread on the soil. Weeders returned after 10 days. Soon the growth became less dense, and the intervals could be made longer. Wurth described the system of keeping fields weeded clean by returning every 10 days and pulling out all weeds. The leaves dropped by the dadap (*Erythrina* spp.) and coffee trees forms a layer of mulch which keeps the soil open and in good condition. This was the so-called "adjowtoel" system also called "Tijil" system after its inventor. This system was based on a methodical organization of weeding so that the weeders came back to the same point after short intervals of no more than 10 days (ten Hones, 1908, p. 668). Thus the weeds had no time to spread. When the system was well applied it was a cheap way to keep the fields clean. This system did not allow digging over and forking of the soil. "No more tearing up of the earth" was the motto (loc. cit., p. 653). The coffee planting and the shade trees were to be kept in the normal growing state (ten Hones, 1908, p. 651). The lecture on the system before the Planters' Conference in Soerabaja in 1907 gave rise to an animated discussion, and it continued for some time in the newspapers, but the "Tijil" system maintains itself up to the present day on estates where conditions are favorable for it and where dadap still thrives. With the disappearance of the dadap it is no longer so effective, since mulch from lamtore (*Loucaena glauca*) leaves does not last as long as *Erythrina*. If the system is once introduced, it can be maintained at a very low cost. According to observations by Wurth, 10 weeders were sufficient for a young

planting of 70 ha. in its first year.

Formerly coffee fields were often dug over in the hope of increasing the yield. In the days of the government coffee plantings, a manual (Heyting, 1887, p. 37) on the whole planting process recommended regular digging. An experiment at Bangelan involving eight years of crop showed no marked influence of this treatment (Jaarboek, 1911, p. 373). A good review of the various systems of upkeep such as clean weeding, selective weeding, "djombret" which is cutlassing and slashing the weeds down, etc., was given by van Wel (1938, p. 1396), with an explanation of the pros and cons of each system. He favored a well applied system of "djombret" and of clean weeding for young plantings, but, generally speaking, the various systems should be combined in accordance with local conditions. A few notes on simplifying the upkeep were recorded by Stadt (1930, p. 845).

It is now a general practice to keep the soil under harmless weeds by selective weeding or by establishing intentionally a cover of specially innocuous plants like Salvia obscura, S. privoides, and Ageratum mexicanum, often mixed with other harmless weeds and cut for mulch. Mulching is an old system. In an "instruction for the cultivation of coffee" of 1789 the native planter was advised to put the plants, removed by the weeding, around the coffee trees to protect the soil from too much and too intense sunlight (Rudin, 1938, p. 999). Practical experience led later planters to adopt this same policy as was pointed out in a lecture by van Doorn (1937, p. 903). In the discussion after this lecture, the general opinion favored keeping the soil under a cover. In another lecture a few days later the same speaker (Prozman, 1937, p. 911) again explained the economy in weeding costs resulting from individual treatment of the fields. Selective weeding aims at giving certain innocuous weeds the upper hand. If noxious plants continued to appear and their removal did not permit the desired weeds to form a thick carpet, the soil was probably not suited for such weeds. According to Ostendorf (1938, p. 878), attempts should be made to find types of plants adapted to the soil and to develop a soil cover from them. Selective weeding may produce results in the beginning, but when grasses continue to appear in an artificial established soil cover, the planter must not try to counteract them by repeated weedings. Rather he must acknowledge that this choice of soil cover was not a good one and try to find another plant better suited to compete with the grasses on his soil.

The effect of various auxiliary plants on the structure and nitrogen content of the soil was studied by Snoop (1941, p. 143). It was found that only a slight improvement of structure and nitrogen content could be proven after keeping the soil under an auxiliary crop for 2 or 3 years. This was the case for leguminous as well as for non-leguminous crops, for carpet formers as well as for bushy plants. The top layer of soil of a few cm. developed a better structure. All these differences related to a comparison with clean weeded soil. Mulching with the cut stems and leaves of the auxiliary crop nearly always had a favorable effect on the nitrate and nitrogen content of the soil under the mulch. This effect was also apparent in a more vigorous growth of the young coffee plants.

Experiments (Coster, 1932 p. 1151) with plants in tins indicated that the auxiliary crop created a root competition which took away soluble nitrates from the soil in which the coffee rooted. In the soil of planting holes dug 10 years previously a greatly improved structure and nitrogen content could still be found. Field experiments proved that a planting's growth was retarded by the presence of weeds; and that there were great differences between the effect of the various weeds resulting from differences in root competition. The whole effect of root competition has been attributed to a competition for the oxygen in the soil. Coffee grown in oxygen-free water was fairly resistant to deficiency of oxygen. Most bushy green manurers tolerated this condition for 20 to 40 days. Coffea excelsa tolerated it for 40 days, and Robusta for 60 days. Coster's article gives an excellent review of the root competition problem in popular form and is well illustrated.

Several workers in Indonesia studied weed effects in the past. A few notes on these may be inserted here. Paria (Momordica charantia) had been recommended as an innocuous cover after 3 months. It did not allow any other weeds to grow, and it did no harm to the coffee if its climbing stems were removed regularly from the coffee trees (C. R. Muller, 1932, p. 1375). Grasses (Paspalum conjugatum, Cynodon dactylon, etc.) were found to be among the most harmful weeds. Salvia occidentalis, Passiflora foetida, and Amaranthus spinosus, were also very noxious. Momordica charantia (supra), Vigna sinensis, Drymaria cordata, Ageratum conyzoides, Nephrolepis biserrata, Portulaca oleracea, Trianthema portulacastrum were not harmful (van der Veen, 1935, p. 64). The main results of these experiments were discussed by van der Veen in a lecture before a planters' meeting (van der Veen, 1935a, p. 961). In the discussion some slightly divergent opinions were expressed by planters. The lecturer mentioned had results from Salvia when used as a cover. Experiments indicated that the root system of this plant excreted some noxious substances into the soil. Although clean weeding gave the quickest growth in young coffee, some bushy green manurers showed little root competition with coffee, especially lantoro and Crotalaria. A scheme for using these two legumes as hedges be-

tween young coffee plants was suggested by van der Veen (loc. cit., p. 966).

In an experiment on the sandy soil of Mt. Kelod described by Snoep (1940a, p. 1296), Salvia obscura was found to be noxious to coffee, although it formed only a thin cover and was kept one meter away from the coffee. The growth of the Salvia was so poor that after 1½ years no mulching could be done. Snoep mentioned (loc. cit., p. 1302) another experiment with various cover plants in which Salvia did not show an unfavorable influence, and he concluded that a general judgment on Salvia was not possible, since the results of the different experiments depended too much on soil and climate.

Together with this experiment Snoep described another, also on Kelod soil, which involved the following treatment: 1. Clean weeding. 2. Clean weeding with application of fertilizers. 3. Soil kept under cover with mulching. 4. Soil mulched with application of fertilizers. 5. Soil mulched, but cut weeds buried in blind drains. 6. Soil mulched and with buried weeds, with application of fertilizers.

In one run of this experiment Ageratum mexicanum (wedgesan goenoeng) was used for the cover, in the second Salvia obscura (creeping salvia). The cover plants were kept one meter away from the coffee tree. The first experiment gave striking results, summarized as follows: The applications of the organic matter, produced by cutting the cover, had a very great effect. Mulching had more effect than burying the material. NP-fertilizer had a great effect. The difference between fertilized and non-fertilized tracts was the greatest with mulching, 585 per cent, and less with other treatments, 172 and 173 per cent. The general conclusion is that mulching combined with NP-fertilizer was very effective. Photographs of the various treatments in both experiments reproduced in the article gave an excellent idea of the differences.

Experiments with water cultures have been made on root competition by s'Jacob (1936, p. 94 and 1938, p. 1366). It was found that when a Robusta plant was put into a culture vessel together with Salvia plants, a plant of a noxious grass called "paitan", Panicum ambiguum, or Centrosema, it was no more thrifty than a coffee plant out alone. Moreover, the coffee plants growing alongside Salvia and paitan were handicapped. This could be reduced substantially by providing oxygen for the root system by blowing air through the water. It was stated in debate by Gandrup, that he had raised coffee plants on leaf mould and observed iron chlorosis in the plants, a condition which s'Jacob attributed to lack of soil aeration (1936, p. 107). All these observations agreed with practical experience, viz., that Salvia did far less damage on well aerated sandy soils than on the compact clay soils. In a later discussion on Salvia (s'Jacob & van der Veen, 1939, p. 176), the opinion of the Djember Institute was that Salvia was noxious under certain conditions. Gandrup (1939, p. 339) explained that opinion had changed, since the noxious action of Salvia was at first attributed to the secretion of some poisonous substance in the soil and later to root competition for the oxygen in the soil.

An excellent contribution to resolving the controversy about Salvia came from van Steenis (1938, p. 1636), who studied the material from a systematic viewpoint and gave full references to the literature. The weed was first called Salvia occidentalis. It was used subsequently by the Forest Service as a cover crop and was applied on a large scale after 1934. Its use spread rapidly. Betrem and Hille Ris Lambers of the Malang Institute thought that there should be a distinction between an "erect" and a "prostrate" form. The question was submitted to the Herbarium at Buitenzorg and van Steenis determined the erect form as S. privoides BTH., the prostrate form as S. obscura BTH. Opinions on the value of the plant as cover were divided. The Research Institute for Central and East Java first considered the erect S. privoides less suitable and the more tender S. obscura a good cover for coffee fields; but it was discovered later that S. privoides, if properly cut, was also quite suitable. The flower stems of S. obscura also had to be cut, for otherwise the plants died. If the plants were cut just before the dry season, and not too low, a beautiful cover was maintained throughout the dry season. The problem was discussed by van Steenis, of whether Salvia was harmful and he concluded that ideal, universally suitable cover plants did not exist and that practice, with its varying demands and often very divergent conditions, should indicate the extent of the use of each plant. It was probable that both species of Salvia had been introduced into Java since the beginning of the century. Van Steenis drew attention to the value of these two weeds to the planter. He asked whether it would not be wise to introduce weeds as well as ornamental and economic plants which can restore depleted soils. Several innocuous weeds which play an important part in the weed growth in coffee fields or in the establishment of secondary jungle are plants originally introduced to Indonesia from abroad but which have become members of the natural flora of the country and here maintained themselves as such. In Backer's review (1936, p. 51) numerous well known plants such as Lantana camara L., Passiflora foetida L., Drymaria cordata Willd., Eupatorium inulifolium H.B.K., and Ageratum conyzoides L. were mentioned. As another example, Leucaena glauca BTH., is now used a great deal as a shade tree and green manurer. The plant must have been intro-

duced into Java quite a while ago from tropical America. It has run wild in many regions of Java, especially near villages under 500 meters above sea level (Backer and van Slooten, 1924, p. 121).

GREEN MANURE PLANTS

After the discussion of the use of innocuous weeds as cover plants we should include some notes on the planting of green manurers. Van Helten (1924) provided in his preface a short historical sketch of the application of green manurers since before 1903 when van Leersum spoke of the use of lupines in Cinchona plantings. Van Helten mentioned the importance of the Cultuurtuin in Bogor for this work. From an old review it appeared there had not been much change in the various uses of auxiliary plants for shade, wind protection, and as green manurers, dating from 1909 when the Planters' Conference took auxiliary plants as its special subjects.

An extensive report with the lectures and discussions at the Conference was published by de Ned. Ind. Landbouw Syndicaat (1909). It contained contributions by research workers and planters. In it Gorter explained the theory of green manuring, and Cramer and de Bussy enumerated the species of leguminous plants used for green manuring. Bernard discussed the diseases and pests of such plants. After these more general reviews a large number of planters contributed their experiences with various green manurers for crops such as coffee, tea, and rubber. Most subjects were thoroughly discussed by those present in the meetings, and the whole report contained a good deal of information on the older green manures.

The tenth meeting held in 1929, of the Association of Research Workers, the Verreniging van Proefstation Personeel, was partly devoted to a discussion of green manuring, and there were several lectures on the subject. Raaf (1931, p. 42) discussed the use of green manurers with coffee and mentioned Indigofera endecaphylla as a suitable cover plant. Reports on the practical results of the older kinds on estates were summarized by van Helten (1913 and 1915); of newer ones, by Ultee (1924a, p. 9) and van Helten (1924). There is additional bibliographical information in a list at the end of "Hulpgevassen" (1939, p. 1702). An excellent description of the various green manurers used in Indonesia was published by Sladden (1931a, p. 367). It contains much data on the principal green manurers of practical importance in Java and Sumatra, on their use, and on their enemies. The beautiful illustrations deserve special praise.

In view of the danger of spreading the berry borer when some of the berries dropped from the trees remained on the soil and were not found by the collecting gang, bushy green manurers were preferable to carpet formers (Friederichs, 1925, p. 112, note).

The shrublike green manurers like Crotalaria anagyroides and C. usaramoensis, Tephrosia candida and T. vogelii, Desmodium gyroides, Indigofera erecta, and others, may be used for turning the prunings into a mulch. The lamtoro, or Leucaena glauca, was sometimes grown as a hedge in young plantings with the same objective and as a protection from wind. Since the young plant was susceptible to a Rhizoctonia disease it was found that the seed had to be planted as early as possible, even in the dry season, so that plants were in a stage less susceptible to the disease when moist conditions prevailed (Vraagbaak, 1941, p. 139). Among the shrublike green manurers, Crotalaria anagyroides was found to be popular (Cramer, 1924a, p. 284) as was Tephrosia candida, which produced still more prunings and could be kept about twice as long, even 3 or 4 years. Data on these green manurers may be found in Vraagbaak, p. 141. Van der Veen (1940, p. 130), who grew young coffee plants together with green manurers in tins, discovered the curious fact that coffee with Desmodium ovalifolium and Indigofera endecaphylla, was more handicapped than coffee without such companions, when the plants received enough water and sufficient quantities of the requisite elements, and when the soil was well ventilated with air. He concluded that the only explanation was the excretion of poisons by the root systems of those cover plants.

The use of green manure plants was aimed at adding valuable organic matter to the soil. A thrifty planting would give 15 to 30 tons of dry material per hectare. Another advantage of planting green manurers was that they helped to prevent erosion.

Koch and Weber (1928, p. 21) made a thorough investigation of the quantities of vegetable matter produced by 28 green manurers and of its composition for the various species. The list comprised most of the popular kinds used then, such as the Crotalarias and Tephrosias. The quantity of fallen leaves was also determined in one series of plots. By arranging the various kinds in the tables according to the quantities of cuttings produced at ages of 2 to 3 months, of 3½ to 5 months, and of 5 months and older, they could be differentiated as early, medium, and late varieties. All data related to solid plantings. For some species high figures were found. For example, Crotalaria usaramoensis gave 354 q./ha. after 3½ to 5 months and later 483 q./ha. of fresh material. C. anagyroides gave 694.1 q./ha. of fresh material after 154 days, equivalent to 175.1 q./ha. of oven dried material. In many cases the quantity of fallen leaves and the amount of nitrogen and phosphorous contained in them were very high. This may explain the favorable action of interplanted green manurers on the coffee. More recent data on green manurers is available in Vraagbaak (1941, p. 141).

In Brasil the green manurers also attracted attention for increasing the humus content of the soil in coffee plantations. An ideal scheme was to apply stable manure on one-third of the estate every year, chemical fertilizers on one-third, and green manure plants grown on one-third, alternating the application for the various fields. At present Canavalia ensiformis is considered one of the most suitable kinds, and another used more recently is Crotalaria juncea. Teixeira Mendes (1940) reported that the former yielded 215 q./ha. of green matter, the latter 362 q./ha. in a solid planting.

KEEPING THE HUMUS

Coffee appears to flourish with a good deal of humus for its root system, and it is well for the humus to be developed in the surface layer of the soil. The ideal coffee soil is old forest soil, with a top layer of half decayed leaves, with a gradual transition into mineral soil (van der Veen, 1934c, p. 1072).

To keep the valuable topsoil, great care should be exercised with the lay out from the very beginning. Even in the old days experienced and careful planters in Java laid out the young fields on hillsides in platforms, one for each coffee tree. This method of planting, when done properly, prevented erosion. It kept the rainwater from running down the slope and forced it to penetrate into the soil. Often a blind drain was dug next to the tree, also to get the rainwater absorbed by the soil as quickly as possible. When the slope was only a slight one, it was sometimes divided into horizontal belts on which several rows of trees were planted and laid out as contour terraces. The individual platforms were, however, the rule, since they allowed the planting of coffee trees in regular rows, an arrangement which made harvesting easier.

When the road systems were marked with slopes not exceeding 7 per cent, the roads were provided with large catchbasins, "fangkuilen", to receive the surplus water from successive parts of the road, so that all the rainwater coming down on the soil was absorbed as soon as it reached the topsoil. This could be further favored by the use of carpet forming green manures or innocuous weeds. In older closed coffee plantings, the planter made an effort to cause the formation of a layer of dropped leaves under the trees. Such a layer of leaves kept the topsoil open and easily accessible to water falling on it and also helped to absorb the rain initially. If planters sometimes made mistakes in the old days, in the time of feverish expansion and the opening of land without measures for protecting the top soil, its loss made itself felt without fail, sometimes to such an extent that the estate would have to be abandoned in a few years.

In his well known book on the soils of Indonesia, Mohr (1938, p. 722) cites the words of a planter who described how a large part of the humus had been lost in the Malang province. But he adds that in the last quarter of a century a great deal of preventive work was done by laying out the fields with platforms, applying green manurers, and using cover crops. The severest criticisms in Indonesia of native coffee planting, aiming at quick but temporary returns, and of the old government plantings, are the waste of humus caused by these forms of cultivation. The loss of humus is difficult to remedy even by the use of costly countermeasures.

A method was developed (de Ligt, 1937a, p. 1766) for keeping as much as possible of the cover on the soil to protect the top layer of humus, to be applied when land was opened for new plantings. The jungle was left in belts, and only the large trees cut. These trees were not used for shade inasmuch as they were too difficult to control. A planting system in rows, for example, 2 x 4 m., was recommended. The bush of the jungle in the belts was gradually cut to small pieces, and the leaves and twigs used as a mulch in the coffee rows. De Ligt tried to combine this method of opening with sowing the coffee directly instead of using plants from the nursery. Although it could be done, the use of nursery plants was still preferable, since the plants from seed demanded more attention. This wiped out the savings from not using nursery plants. The cost of opening with a system of jungle belts was much lower than the cost of ordinary openings. The stand and yield of the plantings were quite satisfactory.

With older plantings, part of the humus of the topsoil often disappeared. An effort was made to bring the soil under the trees into a condition approaching that of fresh forest soil (van der Veen, 1934c, p. 1071); the humus protected from erosion, and from being burnt by direct sunlight. The best policy was to restore and increase the humus by mulching and by planting shade trees which dropped their leaves profusely. Leguminous trees were used for this purpose, and in the old days the favorites were dadap (Erythrina lithosperma Miq. var. inermis = Erythrina subumbrans) and sengon (Albissia falcata Backer). These various shade trees and their treatment will be discussed in a special chapter. Snoop (1937a, p. 1160) pointed out the need for producing a good deal of fresh material for mulching. He suggested that a cover plant, for instance a Salvia, could be cut regularly, but not too short, since the carpet had to be preserved.

The various routines such as pruning the shade, removing the weeds, and cutting the green

manures obviously should be done at an appropriate season. The pruning of the shade trees should be done ideally after the beginning of the rains, when the sudden exposure of the coffee to more sunlight will do it little harm. Weeding must be intensified in the same period, when abundant rainfall after an intensive drought brings the weeds up. During the dry season weeding gangs can go around at greater intervals, but whenever a dry season begins in fields that have been somewhat neglected with respect to weeding, this season is the proper time to bring the weed condition up to standard. This procedure will involve far less work than if it has to be done after the rains have started and when it is already difficult to keep the fast growing weeds under control. The latter part of the dry season is the period when most of the crop comes in, and it requires much labor.

CHAPTER 5 THE CROP ON ESTATES

FLOWERING OF COFFEE

Flowering does not occur until a year or two after planting, and nearly one more year is necessary for the first fruit to ripen for harvesting. In the middle altitude belt the tree starts to produce its first considerable crops at an age of about 4 years. In high altitudes, and with *C. liberica* and allied species, full or nearly full bearing may not take place until even more years have gone by. At the end of the dry season, when the first heavy showers fall at intervals of a few days, sometimes of a couple of weeks, the buds start to appear in the axils of the leaves. When they are about 10 mm. long they stop growing until a good shower permits further development. It was estimated by de Haan (1923, p. 30) that a Robusta tree needed at least a half a liter of water above its normal daily requirement for developing its flower buds into open flowers, and this estimate is probably low. De Haan based his estimate on 3,000 flowers per tree. Snoop (1940b, p. 251) found subsequently, including all flowerings, that the average number of flowers per tree was considerably higher. The lowest figures were 6,000-8,000 flowers per tree, the highest 45,000-50,000.

Water is necessary for the development of the flowers, but it is effective only when the flower buds have reached the proper stage. In an experiment carried on by de Haan (1923, p. 15) at the beginning of the dry season some trees of Robusta received 50 liters of water per tree per one square meter of soil, calculated to represent a shower of rain of 50 mm. No flowering or accelerated development of flower buds took place. About 6 weeks later, when the flower buds had grown during the rainless interval to their full size of 10 mm. but were still resting, the trees were watered again, and 6 or 7 days later a full flowering was observed. When others were watered in the same way a fortnight later, they blossomed in 7 or 8 days. The progress of flower development followed closely the natural course seen when blossoming appeared after regular showers. A technique developed by Hille Ris Lambers is based on this discovery. When an isolated flowering of a tree was desired for crossing, it could be obtained by watering it in the middle of the dry season. Van der Meulen found (1938, p. 416) that in Robusta Bgn. 105.01, at Bangelan the formation of flower buds started in the lowest leaf axils in April. Two months later flower buds were found in all the axils of the leaves. The main flowering took place on the 6 to 7 of August. Observations made in the following year (Frahm-Leliveld, 1938b, p. 127) confirmed that at Bangelan the formation of the flower buds took place at the end of the rainy season. They started to swell about 40 hours after the first heavy shower after the dry season. They reached full size in less than a week and assumed a creamy white color, but were not yet open. These buds called "kaarsjes" or "little candles" by planters were opened early in the morning of the next day, and by some hours later they had started to wilt.

Schweizer, (1939a, p. 1632) studied the physiology of the flower formation, taking as a starting point the C/N theory of Klebs, as extended by Kraus and Kraybill. Sap obtained from the lining tissue was analyzed with the idea that it would contain soluble nitrogenous compounds and sugars, which, by their quick absorption into the plant, would influence flower formation. These substances were formed in the leaves. In the rainy season the proportion of the sugars to the N-compounds was low, for instance, 200 or 300 mg. per 100 cubic centimeters of sap. The water content was high. In the dry season the water content reduced, and the acidity of the sap was higher. This factor probably activated enzymes, such as the amylase, which converts starch into sugar. Also in the dry season smaller quantities of N were absorbed from the soil. The result was more sugar, less nitrogen; the proportion might become 1,500:200. The effect of C/N depended on the water content of the tissues. Those with high water content needed a smaller C/N quotient than those with low water.

This explained why the younger tissues at the tops of branches often flowered before those at the nodes in the interior of the tree. The latter appeared to have a lower water content. These factors seemed influenced by the shade situation of the planting. More light increased the C/N quotient while shade reduced it. Probably pH also had some influence, for vegetative growth was associated with low pH.

Field observations showed that toward the end of a rainy season in February, one sunny day occurred when the relative humidity was 57 per cent. The climate conditions were such that they stimulated flowerbud formation and flowers appeared two weeks later. Such flowerings are small ones called "sprinkled flowerings", by the planters. Large flowerings were at the end of a longer dry period. The C/N quotient was higher then and the water content lower.

When a planting flowered, it was customary in Indonesia for the manager to inspect it and make an estimate of the crop to be expected. This formed the basis for the sale of the crop before harvest. It often had an influence on the finances of the estate, since in a year of a short crop there would be a tendency to economize and postpone capital outlay. Estimates of the crop can often be fairly accurate, but the planter who makes them has to be familiar with the estate and know how it

reacted in former years to periods of rain and drought. A good description of the difficulties involved in estimating a crop with a comparison of estimates and the real crops obtained over a period of years was published by de Ligt (1936b, p. 72), including statistics on rainfall and the successive larger and smaller flowerings of Robusta over a number of years.

It was Snoop who made suggestions in 1936 for more accurately determining the quantity of flowerings by weighing the wilted flowers and for determining the success of the flowering and the setting of the fruit by periodic counts. An estimate of the cost was added. Some of the data were taken from a similar investigation by Deenen (1936, p. 41) on the west coast of Sumatra, a very wet climate. Here various conditions influencing the success of flowerings such as age, position on the tree, and weather conditions during the flowering were studied. In the Amazon region (see Le Cointe, 1922, v. 2, p. 195) at about sea level with a consistently warm and moist climate, it was found that arabian coffee flowered and fruited the whole year through so that flowers, and green and ripe berries, could be found on the same tree, at the same time.

In some years only one flowering took place on C. arabica in Java, while C. robusta sometimes showed several heavy flowerings. With C. liberica and allied species the flowerings were spread over the whole year, although the main flowerings occurred after the rains had set in, at least in a dry climate. In a wet climate, with no intensive, long dry season, several flowerings were the rule with all these species. At Bangelan flowerings of robustoid kinds were observed from this viewpoint over a period of 3 years. It was found by Ferwerda (1933, p. 312) that with robustoid species two types occurred: forms with one sharply defined flowering, which comprised mostly pure C. robusta, and forms which flowered, through the whole year, to which group belonged such as C. quillou, C. congensis, C. uganda, Uganda-like Robusta, and some pure Robustas such as Ngn. 59.01.01 and Bgn. 78.11.Bgn 105 and its seedlings, and Bgn. 124.01 which always flowered one or two days later than the others.

Not all the flowers which opened set fruit, even when weather conditions were favorable. The principal causes for serious failure were:

- a. Drying of the flower buds from a prolonged dry season.
- b. A small rainfall at the end of the dry season sufficient for making the flowers grow or even open, but insufficient for a healthy blossoming.
- c. Rain on the open flowers.
- d. Dropping of the set fruit.

It may be possible that some influence could be exerted on the opening of the flowers by certain treatments of the soil or of the shade (Ferwerda, 1933, p. 311). If rain came down on the open flowers, the pollen was largely lost. The stigma was more resistant and could still be fertilised the following day if there was some fresh pollen (Ferwerda, 1937a, p. 147).

SHEDDING AND OVERHEARING

We have already noted that part of the fruits set after the flowering are later dropped. In 1934 Pfaltser (1934, p. 1094) gave some figures on the dropping of young fruits of Robusta after the flowering. Under favorable circumstances 40 per cent of the flowers might develop into ripe berries, but generally the figure was only about 20 per cent. Several factors that might influence fruit drop were considered in his article.

Three periods could be distinguished during the time when unripe berries were shed as follows:

- a. Shortly after the flowering the young fruits were dropped which had failed to develop an embryo sac.
- b. Several months after the setting, small berries were shed in a chain of events in which development of the embryo sac had already stimulated the swelling, but in which no fertilisation had taken place, partly because of insufficient pollination, partly because of failure of the fertilization.
- c. There was shedding in April only a few months before the ripening had set in, but it appeared that fruit development had been normal up to this point. The causes were probably physiological in origin (Frahm-Leliveld, 1938b, p. 148).

A very heavy crop may harm the tree, especially C. arabica, since it exhausts the tree, making it drop its leaves. It may even cause die-back of branches.

Schweizer (1940a, p. 165) investigated the influence of the ripening of the crop on the composition of the leaves. A normal crop did not withdraw ash- or N-constituents from the leaf, but there was a withdrawal of these elements from the bark and wood of the branches. A large flowering took N from the leaf and thus increased the total ash content of the leaf.

A large crop caused a serious die-back in the branches of C. arabica. The same thing occurred where there were much larger crops of C. robusta. In these cases the organs of the tree were mobilising N- and ash-constituents. P might decrease up to 60 per cent of the original amount.

Starch disappeared completely. Total sugars decreased to 4 per cent of the control samples.

The amounts of N- and ash-constituents of the coffee bean were at a maximum 4 to 5 months before ripening. Up to this time there were no signs of overbearing on the tree. The consumption of carbohydrates during the period when the berry turns red was enormous. Therefore, Schweiser considered, it could be assumed that die-back, caused by overbearing, was a symptom of deficiency of carbohydrates.

Die-back in robustoid coffee was not the beginning but the end of the phenomenon called overbearing. The carbohydrate reserves of branches, stem, and roots had disappeared, and the beginning of die-back of the branches was the beginning of the decay of the whole tree.

In East Africa, die-back of arabian coffee was generally associated with overbearing (Nutman, 1933a, p. 293). There appeared to be a tendency for the coffee tree to set and to attempt to mature a crop of such size that the reserves of the tree were unable to supply the needs of the developing fruit. Overbearing caused die-back of the roots, and no evidences of regeneration were observed.

RELATION BETWEEN FLOWERING AND A CROP

The Research Institute for Central and East Java (Gandrup and Snoep, 1935, p. 641) tried to secure a better insight into the factors influencing the success of flowering, by sending out a questionnaire to Robusta growers. The estates which replied were divided into two groups, 9 with a dry climate and 9 with a wet climate. The first had 4 flower periods, with a main flowering at the beginning of August, while the wet estates had 12 flowering periods. The two largest flowerings took place at the beginning of August and the beginning of September. In the following year 70 per cent of the crop on the dry estates came in during June and July, and these were also the harvesting months for 40 per cent of the crop on the wet estates. The ripening of the berries took 10 to 11 months for both groups. On the wet estates flowerings estimated as corresponding to a crop of 10 piculs gave only 5 piculs per bahoe (4.5 q./ha.), while on the dry estates the estimate from flowering was 10 piculs and the crop obtained was 11 piculs per bahoe (10 q./ha.).

From the data given above it is clear that the individual factors governing a set of seedlings of a single clone also play their part in the reactions of the trees to these external conditions, and they influence the quantity of coffee produced. Analysis of internal factors and their influence on yield is known to be one of the most difficult problems in this field. Even in the more advanced study of crops of the temperate zones the very complexity of the problem has prevented most geneticists from attempting detailed analysis of these (Hudson, 1937 p. 314). Hudson cites the names of Engledow, Heuser, and Rasmussen in this connection. The latter calculated that 100 to 200 separate genes are concerned in the inheritance of quantitative characters such as yield, quality, etc. In coffee we are still far from understanding even the simpler aspects of the complicated process of setting the crop.

An endeavor to get a better insight into the results of flowerings and their effect on the yield was made by Snoep (1940b, p. 247). His formula expressed yield per tree in 3 terms. The first was the number of flowers, determined by weighing all wilted ones. The second the percentage of success, found by calculating the number of berries collected by dividing the weight collected per tree by the average weight per berry. The third term was the output, which meant the quantity of market coffee obtained per unprocessed berry, that is per successful flower. The formula is then: number of flowers x percentage of success x output = yield.

The output weight of market product per berry depended on the weight of the bean, the percentage of round beans, and the percentage of berry borer damage. An increase in the number of flowers, or in the percentage of success, might result in a reduction of output per flower. It was once thought that a low percentage of success might be accompanied by a high percentage of round beans, but this was not found to be the case. Although there were pronounced differences in percentage of success for flowerings opening under different weather conditions, the percentage of round beans did not vary much for successive picking rounds. This led to the conclusion that the highly successful flowerings when compared with flowerings for which the percentage of success was low, gave an equal percentage of round beans.

Snoep applied this system of analyzing the factors determining the yield of the year, a comparison of climatic factors, estates in dry and wet climates, and comparison of clones. The percentage of success seemed to be a clonal character, less dependent on external conditions than the number of flowers. A comparison of Robusta trees under different shade conditions "dark" and "light" showed a favorable influence of "light" on the number of flowers. Snoep concluded by explaining that several questions could be answered by applying his formula to crop estimates, for instance, whether in a small crop the number of flowerings or the percentage of success was low. All these data showed how much the yields depended on external conditions, and they exercised their influences until the crops had been brought in.

VIRESCENCE OR ABNORMAL, ABORTIVE FLOWERS

As a special factor which may affect the success of a flowering, the occasional virescence of the flowers must be mentioned here. Unfavorable weather conditions, for example a dry spell of 2 to 3 weeks during the rainy season, may lead to the formation of "sterretjes". This term means "little stars" and is applied to flowers which remain small, with stiff, greenish petals. They present a case of virescence, as described by Delacroix (1911, p. 14) and they do not set fruit. External conditions have appeared to cause this abnormality and led to a considerable reduction of the crop, mainly with *C. arabica* (Schweizer, 1935a, p. 437), although virescence also occurred at times in robustoid and liberoid species. The question of the "little stars" was discussed from the planter's viewpoint in 1900 at a planters' meeting (Kedirische, 1900-1901, p. 917) where Ottolander's ideas and observations on this matter were mentioned.

The degree to which virescence occurs may vary a great deal. In the Cultuurlijn in Bogor, in a very wet climate, *C. quillon* and hybrids of it with Robusta (for instance the so-called Robusta Bgn. 124) often developed flowerings consisting of white flower, which still remained close to the "candle" state. The flower bud opened its petal lobes which remained greenish white only at the top, and the fruit did not set. In an extensive study of the "little stars" von Faber mentioned that he frequently observed abnormal, small, greenish-yellow or yellowish-white flowers in *C. arabica*, less frequently in *C. liberica*, and only exceptionally in *C. laurentii*, *C. ugandae*, and *C. quillon* (von Faber, 1912, p. 133). He described genuine "sterretjes" in which the petals were reduced and thick, numbering only 3 to 5 and with no calyx. The anthers were petal-like, and the whole construction of the female organs indicated sterility, a fact confirmed by cytological examination. He considered these as flowers whose normal development had been arrested. Adverse conditions such as insufficient light, excessive soil moisture, and possibly poor soil or exhaustion by diseases, were responsible (loc. cit., p. 154). Zimmermann (1904, p. 76) also thought that external conditions caused the "sterretjes". He gave a good picture of the various degrees to which the abnormality might develop with buds of *C. liberica* and pointed out that trees next to each other showed very large individual differences in the proportion of normal and virescent flowers (loc. cit., p. 82).

Schweizer (1935b, p. 72) started preliminary experiments on the question of the external factors influencing the formation of "little stars" and made many observations on their occurrence. He concluded that apparently there was a gradual transition between the formation of flowers, the formation of "little stars", and branch growth. In his opinion the virescent flowerings should be considered as an intermediary form between the vegetative and generative growing phase.

Seedling trees were sometimes found on which all flowers developed into "little stars" and where the abnormality was transferred when grafts were made. Such trees were known for robustoid and liberoid species. Several clones showing this formation were included in the collection of the Besuki Institute. Here the formation of "little stars" was a constitutional characteristic due to internal factors. Sometimes the virescence might go so far as to turn parts of the flower into real leaves, a process which Pensig (1921, v. 1. p. XI) called "Verlaubung".

RIPENING AND HARVESTING

It is well known among planters that if a shower occurs during the ripening of the crop in the dry season, it affects the trees at once, stimulating the ripening, so that the effect is felt in a few days in terms of increased quantities collected during the picking rounds. Such a factor may, however, make a difference of only a few days. The duration of the ripening depends on the time the flowers open. It was reported by de Ligt (1936b) that for the earlier flowerings in Robusta, the ripening of the crop required 12 months, for the later ones 11 months (ibid, p. 74 and p. 82). Hille Ris Lambers also found a longer ripening period for earlier flowerings and cited a case where ripening took 14 months (de Ligt, loc. cit., discussion, p. 83).

Generally speaking, the duration of the average period from flower to ripe berry is fairly stable from year to year. At Bangalan robustoid flowers were observed for several years. It was found (Perwerda, 1937, p. 198) that for Robusta, Congusta, and "Liberica-Arabica Hybrids" the period from flower to ripe berry was 10 to 11 months; for *C. quillon*, 9½ months; and 11 for Robusta-Eucelca Hybrids, such as QP., about a year. The length of the period did not vary a great deal from year to year. The averages for the various clones varied much more; for an early ripening clone such as R. Bgn. 59.01.01 the period was short, under 300 days, for a later ripening clone such as R. Bgn. 105.04, it was from 316 to 354 days. When flowers of a certain clone were pollinated with pollen from various other clones, there was no difference in the average duration of the ripening period, which remained true to the average characteristic of the mother clone.

In Indonesia the picking of Arabica and Robusta goes on from the beginning of the dry season until the end. With liberoid kinds and hybrids, fair quantities also would come in after the end

of the dry season and at the beginning of the year, before the dry season had set in. The fallen berries as well as the red ripe berries were picked on each round. It was recommended that all the black desiccated berries under the trees and on the branches should be carefully collected because of possible borer infestation. These fallen berries, called "lelessan", were used in the second grade market product. Formerly the excrement of the coffee rat or *loewak* (*Paradoxurus hermaphroditus*), which contained mainly coffee beans in the parchment skin when the animal had fed upon coffee berries, was carefully collected and brought in. It was washed, and the clean beans were segregated and cured. They were said to constitute a very good grade of coffee, since the animal selected ripe berries for its food.

The organization of the harvesting and the method of payment were described by Sladden (1931, p. 305). A woman picked an average of 30 to 35 kg. of berries per day. During the first picking season the daily harvest might be greater, especially should the transportation en to the factory be easy.

It was the habit, 20 or 30 years ago, for the harvest to be received from the picking women in a measure on which a scale could be fixed to indicate at once the amount to be paid. This payment was adapted to the size of the potential daily crop. During the full crop a picul of berries could be collected in one day. In the beginning and at the end of the harvest, when ripe berries were scarcer, a day's picking was a much smaller quantity. In more recent times the measure was largely abandoned but in easternmost Java, planters have stuck to the old system. After some negotiations with the Service for Stamping and Verifying Weights and Measures, an agreement was reached under which a standard "takeran", or the measure for coffee berries, was legally approved (Anon., 1934, p. 47).

On estates where harvesting is well organized, intervals between picking rounds are about 3 weeks to prevent the dropping of overmature berries. Often when the harvest was brought into the factory, the desiccated, black, unripe, green and beetle-damaged berries were kept apart from the main crop and cured separately by the dry process for a second grade product or "glondongan coffee" (Ringoet, 1935, p. 8).

CURING

The whole process of curing coffee, with data on the machinery used, estimates of costs, and many useful hints, were described in a concise, but complete and well illustrated note by A. Ringoet (1935). Estates used a power driven factory for the curing of the crop by the "wet process" or West Indian curing. This method required a good deal of water, popularly estimated at one cubic meter per picul (61.76 kg.) of market coffee. In very dry years some estates found they could manage with much less (Ultee, 1926, p. 167). In 1928 (Knaus, 1929, p. 27) the Malang Institute organized an inquiry on the curing of coffee on the estates of Java and southern Sumatra. The questionnaire was filled in from 149 estates, many of which gave a plan of the factory. The data related almost entirely to Robusta. The whole constituted a complete description of the situation at the time and enabled Knaus to give several useful hints for improvements. He recommended sorting the fresh berries into two sizes to make the pulping, drying and grading easier and reduce the percentage of off-quality beans. He further advocated increasing the capacity of the plant; discarding of borer damaged beans during the course of curing; increased dryer capacity for peak load; increased mechanization of transportation inside the factory; and improved arrangement of buildings and machinery.

In the wet curing process, as carried out in Indonesia the berries are received from the picking gang at the factory and passed through a conical receiving tank filled with water. The empty, dry, and beetle-damaged berries float and pass over the edges. The healthy berries sink and are sucked away from near the bottom by a siphon pipe which brings them to the pulper. A tube at the bottom of the tank drains the residus of sand, pebbles, etc. In the pulper, the beans are pressed between a roller with a knobby surface and a fixed plate of metal set so that the opening between the two becomes constantly narrower and the squeezing action bursts open the berries. The skins stick to the uneven surface of the roller until removed from it by a rubber blade and then are ejected through an opening in the underside. The beans, divested of the skin and part of the pulp, emerge from the upper part of the machine. The skins are often used for making compost. Sometimes they were burned for heating the drying house. With skins used for fuel, the furnace was provided with a special grate, or the skins were pressed into briquettes. In the latter method skins were kept in heaps for 8 or 9 months. The mass was then kneaded with the feet, treated with crude oil to keep insects away from the finished briquettes, pressed into moulds like bricks, and dried. The cost was estimated at 1.50 guilders per 1000 briquettes. Briquettes were also made by adding clay as a binder but the cost was higher (Lisnet, 1918, p. 831). In later years the briquetting of skins for fuel has largely been superseded by using them for compost.

Attempts have been made to improve the machinery for pulping. In 1937 a new pulper for Ro-

busta was described (de Draayer, 1937, p. 1810). It was designed to improve the separation of beans and skins after the pulping by the action of a second cylinder with a knobby surface, next to the first one and turning in the same direction. The new Draayer pulper was said to be especially suitable for pulping green berries. When these were fed to the new pulper, a large percentage of the pulped beans were rubbed against each other between the two cylinders and thus divested of their parchment skins. They became the "white beans" ("witboon"), so-called because they showed the white endosperm, free from the green silverskin, when coming from the pulper. Another kind of pulper, the "Raolug" pulper, which found a place in the industry was so constructed that it removed both the skin and the soft pulp, delivering coffee which needed no fermenting.

The pulpers more commonly encountered, were like those in other countries. The removal of the pulp was effected by fermenting the beans in large masonry tanks in which they were left under water for one or two days, sometimes with one change of the water. In order to avoid too many skins in the parchment coffee, a "separator" was often interposed between the pulper and fermentation tank. This was a gutter arrangement with a bottom of lengths of wire through which the heavy beans passed, while the lighter skins floated in the water (Ringost, 1935, p. 20). Fermentation softened the glucose layer so that it could be washed away. This was often done in a large flat washing tank, where men with wooden rakes and shovels moved the beans through the water and removed the slime and remaining skins. Beans still attached to skins were put aside, and after drying skins were removed in the huller. The skins obtained from the various machines were turned into compost. It was found that 100 kg. of berries yielded 0.1 cubic meters of skins which made 0.03 to 0.05 cubic meters of compost. Washing can also be done by machinery, and there is even a cleaner in which unfermented pulped beans can be freed from the pulp. In the ordinary washers this can be accomplished by treating the beans with wood ashes or lime. A description of such a washer, with figures for the output per hour (30 piculs, 20 q. per hour) stressed saving of labor (van Os, 1920, p. 317).

With Robusta the fermentation process was found to depend (Groenevege, 1928) on the action of Bacterium lactis aerogenes, which attacked the membranes of the pulp cells. Draining the liquid during fermentation and replacing it by clean water accelerated the process. The water was replaced 6 to 10 hours after the pulping, when the fermentation was well started. On estates in lower altitudes, where the water had a higher temperature, this period could be reduced to 5 or 6 hours after filling the fermentation tank. The quantity of water to be replaced was about a third of the content of the fermentation tank, and was gradually added during the entirety of the second fermentation period, while the fermentation water was simultaneously draining from the bottom, where it came out as a thick, viscous liquid with the characteristic smell of fermented products (Doornberg, 1930, p. 134). The fermentation was finished when a small sample of the parchment beans was easily cleaned of the slimy pulp with some running water.

Later investigation indicated that in the case of Arabica the fermentation was an enzymatic process in which micro-organisms played a role of secondary importance. In the case of Robusta the process was probably analogous (Ultee, 1934c, p. 285). In a publication by Frits (1935, p. 44) it was confirmed that the fermentation of C. arabica coffee was an enzymatic process which could be accomplished without micro-organisms. Frits obtained complete disintegration of the "glucose" layer after having rendered the micro-organisms inactive and keeping the beans at a temperature of 40° C. Various substances added to the pulped beans were found to disintegrate the glucose layer at once, without fermentation, since they attacked the pectate of lime, which cemented the cells of this layer together. Soda, wood ashes, and the juice of unripe papaya could be used in a similar manner (loc. cit., p. 72). Ultee, who published an abstract of the article in Bergcultures (1935, p. 631), expressed his conviction that what was found by Frits for Arabica would also apply to Robusta.

That fermentation is not necessary was explained by Ultee (1928, p. 130), who cited favorable opinions on coffee cured without fermentation and described various methods of omitting the process. The purpose of fermentation was only to wash away the pulp more readily, and it had no influence on the quality of the market coffee except that when it was continued too long it gave an unpleasant odor to the product. Similar experiments conducted in the Belgian Congo gave the same results (Wilbaux, 1937, p. 23). Fermentation of 12 to 24 hours was found to be sufficient. The coffee prepared by fermentation was offered a better chance for pure taste (le Conge, 1934, p. 657).

Roelofsen (1939c, p. 176) cleared up the contradiction existing about the nature of the fermentation process. He found that the mesocarp of ripe beans, especially of Arabica, contained an agent which disintegrated the cells. It was composed of an enzyme and some other substances. This agent appeared to be the main cause of maceration during fermentation. Purely chemical softening of the protopectins of the middle lamellae also played a part, since they can be dissolved by diluted solutions of organic potassium salts. In aerobic fermentation, bacterial and yeast enzymes contributed to this process. With anaerobic conditions the effect of the lactic bacteria was to kill the mesocarp cells and skins and to free the enzymes in them (Roelofsen, 1939c, p. 276).

Special mention must be made of difficulties of curing *Liberica*. These difficulties were frequently discussed in planters' meetings, for instance, in Soekaboemische Landbouwvereening (1900-1901, p. 340). The very thick, hard skin of the berries made pulping by machinery constructed for the soft berried *C. arabica* nearly impossible, and the thick glucose layer, less juicy than that of *C. arabica*, made for difficulty in fermentation, which frequently had to be prolonged for 5 or 6 days. The difficulties of the hulling were explained by Lange (1897, p. 51). When the problem of pulping became urgent, several planters' associations came together and organized a private competition for the best pulper for *C. liberica* (Mulder, 1896, p. 577). One association voted 3,000 guilders for this purpose (Indische Mercur, 1892, p. 268). The prize was given on 19 January 1897 to Butin Schaap (Loc. cit., 1897, p. 156). His pulpers were soon in use on estates (Loc. cit., 1898, p. 273). That the pulper won popularity rapidly may be concluded from the fact that soon after it had appeared on the market, 75 were sold (Butin Schaap, 1898, p. 78). Another new pulper for *C. liberica* was mentioned about the same time (Liberia koffiepulper Lyon, 1897, p. 27).

Butin Schaap applied an entirely new principle in his pulper. The berries, after a preliminary treatment in a squeezer, fell on two rollers set at a small distance apart and turning towards each other. Both had surface grooves in a screw line. The skins were taken by the grooved surface and passed between the rollers to an outlet, while the beans in their glucose layers remained on the surface of the rollers and moved by the action of the grooved surface toward the end of the rollers, where they came to an outlet. A description of the new pulper was published in 1898 (Butin Schaap, 1898, p. 98). The merits of the new pulper caused some controversy among the planters. A criticism of the new pulper and a favorable judgment on another designed by G. van Riemdijk, was published by van Maanen (1901, p. 62). Butin Schaap replied to it (1901a, p. 100) and was supported by a fellow planter, Wattendorff (1901, p. 149). A picturesque description by Leembruggen (1901, p. 167) of the way a pulper for *C. liberica* was constructed with primitive means, contained some practical hints.

There was also controversy among the planters on the problem of fermentation. If the fermentation took several days, the coffee acquired an acid odor which was considered a bad characteristic on the market (MacGillavry, 1898-1899, p. 45). All kinds of solutions were proposed, and inquiries were organized. A long list of references to this discussion might be cited. The results of an inquiry on the various methods for curing *Liberica* in Java were published in 1899 (Indische Mercur, 1899, p. 667 and p. 782). In later years Fernandes (1930, p. 647), working in Surinam where *C. liberica* was one of the main estate crops, found a new method for eliminating the acid odor by drying the beans at a high temperature (Fernandes, 1930, p. 650). This whole investigation by Fernandes is a good piece of work.

At first Fernandes (1928) studied the causes of the disagreeable flavor of *C. liberica* as cured on the Surinam estates. The condition was attributed to a lipolytic enzyme. It was found that the enzyme could be destroyed by heating the beans quickly to a temperature of 80° C. In a small container this temperature could be reached in less than three hours by passing air heated to 80° C. through the product. The coffee was then free from the disagreeable taste, but the color was "blue", lead grey, instead of yellow. Samples of the product cured by the new method were submitted to coffee experts in Europe and in America, who gave favorable opinions on the improved taste (Verslag Surinam, 1936-37, p. 106-108). An experimental factory was constructed in which the pulping was done at first by a Schaap pulper. However, this machine did not separate the pulped beans well as some of them were crushed by the spiral rollers and thus were lost with the skins. The berries were then passed through a squeezer, and the skins were separated in a "skin gutter" with slanting, perforated partitions which allowed the beans to pass to a space beneath, from which they could be removed. Then they went to a washer and were dried. The loss after pulping was greatly reduced, and the washing made it possible to do away with fermentation.

In 1936 and 1937 several experiments were conducted, drying larger quantities of coffee by air heated to 350° C. The product had to be heated in four hours to a temperature of 80° C., a treatment which rendered certain enzymes inactive. However, this method was not found to be practical. The same result could be obtained by immersing the beans before drying in water heated to 90° C. for fifteen minutes, and the product could then be dried as usual. This method was further improved by heating the beans with steam under a pressure of 3 to 4 atmospheres for three minutes in a container through which they were moved by a worm. The end product was similar to the product obtained with the former methods. However, the color was blue grey, and the Dutch merchants preferred yellow *Liberica* coffee. In the United States the color was considered less important. The taste of the treated coffee was much better.

An attempt was then made to keep both the yellow color and the improvement in taste. This was finally accomplished by immersing the beans in a solution of nitrate of potash, eight parts in a thousand parts of water, after pulping, fermentation, and washing. The treatment cost a quarter of a cent per kg. of market coffee (Verslag Suriname, 1938, 1939, p. 70-74).

DRYING AND FURTHER FINISHING

The clean, wet parchment coffee must be dried before shipment. According to Knaus (1933, p. 711) this important part of the curing process was aimed to rapid and regular drying with a great deal of air and at low temperature. Sometimes pre-drying is done by spreading the beans in the sun on a drying floor. It has been found with Robusta coffee that 100 kg. of wet parchment with moisture content of 55 per cent, would yield 50 kg. of clean market coffee with a moisture content of about 5 per cent. About a fifth of this water was determined as adhering water. If the beans were spread thinly, and the weather was favorable, the moisture content could be lowered from 55 to 45 per cent. On a dripping floor a reduction to nearly 50 per cent was obtained. Centrifuges have been used but were not found to be efficient, since they lowered the water content no more than drying on the floor.

Roelofsen found (1939c, p. 163) that Robusta beans were killed during the drying process. Robusta beans were killed when the water content was reduced to about a fifth, Arabian somewhat later. Heat killed the beans only when the temperature rose above 55° C., and this killing fixes the bean in the end stage. During the drying in the drying house, some beans died earlier than others, probably by direct contact with the heated plates.

The drying of coffee in Indonesia is done in a special drying house. In this building a set of iron heating tubes near the floor connect tunnels next to the short walls on either side with u-shaped collecting tubes, which in turn open into the bases of a chimney. There is a fireplace at the entrance to each tunnel. Openings in the walls under the level of the heating tubes allow the outside air to come in under the heating tubes. Above them, at a height of 5 meters from the ground, there is the drying floor, made of perforated iron plates, each three by six feet, and surrounded by a wall one meter high. A couple of meters above the floor is a galvanized iron roof. Such a drying house operates as follows: Fires are built in the fireplaces, and the gasses circulate through the tunnel, then through the heating tubes to the collecting tubes which convey them to the chimney. When this whole iron system is being heated, the outside air entering through the holes in the wall is also heated and rises to the drying floor and through its holes. It circulates through the parchment coffee, takes the moisture out of it, and escapes through the open sides.

For uniform drying, the coffee on the floor is frequently turned. At the beginning, the temperature of the air is kept high at 90-100° C., and the beans are worked over intensively. When the beans have lost half of their moisture so that it is reduced to about 30 per cent, the temperature is brought down to 50-60° C., and the beans are dry in about 22 hours. Since the emptying and filling of the drying house takes two hours, a new batch can be put on the floor every 24 hours. The usual quantity is 45 kg. of market coffee per plate, which corresponds to a layer 8 cm. thick. Generally the capacity of such drying houses is expressed by the number of plates. For instance, a drying house with 72 plates has a capacity of about 50 piculs, roughly 3 tons of market coffee per day. The market coffee is judged dry when the beans are "glass hard". This is the stage when a bean hit by a hammer flies into several pieces. When the whole curing process is done well, and it requires constant supervision, $\frac{3}{4}$ to 1 kg. of good firewood is sufficient to dry one kg. of coffee.

Instead of the common drying houses in which the coffee beans have to be stirred by hand, newer types of driers have been developed. These may be used for the whole drying process or for the first stage of drying, with the final drying done in a drying house. Two types have been constructed called: the turret dryer and the rake-carrier dryer. The first type gave fair results, and the second was also considered promising, but some modifications were thought to be necessary (Knaus, 1934, p. 241).

In the processing, the dry parchment coffee had to be freed from both the parchment skin and silver skin. This was done in a huller, where the parchment skin was removed. Sometimes it was polished at the same time. The skins, about 16 per cent of the weight, were often used as a fuel for the drying house. It was found advisable to keep the dried parchment beans for one or two days before hulling so that they absorbed some moisture, since the beans as they came from the drying house were quite brittle and might break in the huller. In the case of species such as Robusta, Liberica, and their hybrids, the silver skin was not so easy to loosen as with Arabica. It was found essential to start the drying at a high temperature, since this cracked the silverskin. Sometimes drying at a high temperature was not feasible as found by Keller (1903-1904), in that the silverskin might have to be removed by special treatment, used particularly with Liberica. The beans were dried and hulled, and the dry market product soaked a moment in boiling water and then immediately dried again.

In field processing, beans are graded for shipment. In Indonesia some estates graded the ripe berries, classifying them in 2 or 3 sizes. This method had an advantage in that pulpers and hullers which were set according to the size of the bean, worked more efficiently, and fewer berries passed, unpulped or fewer beans were broken. Impurities in the end product, such as parts of skins, beetle-damaged, partly empty beans, etc., could be removed by a pneumatic sorter. In other countries the

discarding of inferior beans was often done as the dry product passed before the operator on a travelling belt. The coffee was deposited in a hopper, the bottom of which served to distribute a thin layer of coffee evenly on the travelling belt (Ugarte, 1920, p. 265). This appliance was rarely used in Indonesia. Here the final sorting was done by hand. Black beans, unhulled parchment beans, or dried berries were removed, and the market product called "telquel", obtained. In this grade one half of one per cent of broken and black beans and 5 per cent of beetle-damaged beans ("boeboek koffie") was allowed. Usually the market coffee delivered by estates as "telquel" quality contained less than 5 per cent of boeboek beans (Le Conge, 1934, p. 655). F.A.Q. or Fair Average Quality could contain only one half of one per cent of broken, black or burnt beans and 2 per cent of beetle-damaged beans. The second grades, consisting of the green berries, the berries found on the ground, called "lelessan", the beetle-damaged berries, dry berries at the end of the crop, skin coffee, etc., were worked separately by the dry process.

For small estates producing 800 to 900 quintals of market coffee, a much simpler factory was used where the crop was pulped and fermented but where a modification of the dry process was applied. Ripe berries were passed through a squeezer which opened the berries and took away part of the skin. Then the whole mass of squeezed berries and coffee beans still in the pulp, was dried at once in a drying house at a high temperature and afterwards passed through a huller. The market product resembled the W.I.B. (wet west Indian method) product in color, but the odor was more like that of coffee dried in the hull. A factory with its motor, and a drying house of 20 plates with a capacity of 10 to 15 piculs or 6 to 9 quintals, of market coffee per day, cost about 8,000 guilders (description and drawings in Knaus, 1929a, p. 1295).

In other countries opinions have been expressed in favor of the dry curing process, and it has the advantage of being simpler. It is ordinarily held that the capacity of the drying house has to be double that of the one required for the wet process, but the waste of dried berries -- about 33 per cent, with a fuel value of about 4,000 cal. per kg. -- is nearly sufficient for carrying out the drying.

CHAPTER 6 PRODUCTION BY NATIVES

PLANTING METHODS

Apart from the production of coffee on the European-owned estates, an important coffee planting industry developed among the natives on several islands in Indonesia. Arabian and Robusta coffees were both involved. This industry has developed its own methods which are particularly suited to the native economy.

In Sumatra the native often planted coffee with "hill rice" for one or two years, sometimes followed by still another crop of potatoes or vegetables. In one of the important native coffee regions, the Ranau district, Arabian coffee was originally planted, and it is still the principal kind at the higher altitudes. In the lower belt Robusta has been most used. When the neighboring European estates started to produce crops of Robusta up to 20 quintals per hectare, the natives noted these high yields and in about 1915 began to plant the new kind instead of Arabian coffee. When it was discovered that the new kind was less exacting with respect to soil and upkeep and more suitable for the lower regions, extensive plantings were made in the more accessible lower hills (Rudin 1936, p. 267). In the region of Kerintji the introduction of Robusta dates from 1916 and was due to government officers assisting the natives (de Boer, 1937, p. 201). A rapid rise in the production of Robusta in southern Sumatra by the natives was noted about 1923/24 (Cramer, 1924a, p. 245). A good description of the native coffee planting industry in Sumatra, based on visits to the fields, was published by Huitema (1935). He reproduced excellent photographs and included a map of the principal centers of Robusta and Arabica production; this is one of the few books on coffee production in Indonesia which considers the oldest literature and cites it.

In many regions coffee came after the hill rice. It was kept up only for about 5 years and then abandoned. Every year a new field was opened, but if the new field had ever been in coffee production, the soil needed to be rested for 7 to 10 years, and for an even longer period for poor soils. From an economic point of view the native system of maintaining the coffee planting only a few years and opening new land every year has proved to be a defensible system. In southern Sumatra with its very wet climate, Robusta gives the heaviest yields in the first cropping years. The drawback is that this policy may lead to a serious destruction of virgin forests and their replacement by grass plains, that may have grave effects on the ground water supply.

The Arabica plantings in Bali contrast sharply with this short-term Robusta cultivation in the wet climate of Sumatra. In Bali the *C. arabica* was planted at higher altitudes on loose volcanic soil and was more permanent. The manner in which the fields were kept under shade with an undergrowth of innocuous weeds gave the plantations more or less the character of forests. Since "hydrologic" forests, that are important for preserving the water supplies, are limited and the area cannot readily be extended, the government took legal steps to protect coffee plantations against destruction (Koffierooikeur of 13 March 1936, no 17, in *Javasche Courant*, no 21). Such plantations in a measure took the place of protecting forests. Under these regulations owners of coffee plantings were not allowed to use their coffee land for purposes other than its production without special permission.

The native technique of planting robustoid coffees in Sumatra has been rather primitive and in some respects reminiscent of the old practices of the government coffee plantations. Volunteer plants 6 to 9 months old often have been used as planting material, with planting distance dense, and upkeep not too good. Shade trees were seldom planted, but the Renau region appeared an exception in this respect. In other regions coffee was sometimes planted between rubber trees. In the lower belt of the hilly land of Palembang this situation existed as early as 1928. There the rubber pushed out the coffee (Kroon, 1928, p. 36). Various diseases and pests did much harm to the coffee crop and the trees (Huitema, 1935, p. 153). The agricultural teachers had some measure of success in introducing better methods of cultivations, the use of improved seeds, and so on.

In native coffee plantings green manurers were seldom used according to Huitema (1935, p. 201). He contrasted their favorable effects from soil improvement, protection from wind, and preliminary shading, with their disadvantages, the danger that when neglected they might shade out the coffee, effects from root competition, and the expense of upkeep. Therefore, the use of bushy legumes was not recommended except for slopes as a defense against erosion. Carpet formers like *Calopogonium* and *Centrosema* required too much upkeep. *Indigofera endecaphylla* Jacq., was mentioned as a cover plant which had given satisfaction on coffee estates. Huitema cited the literature on this plant and explained its advantages and disadvantages.

The combination of rubber with Robusta coffee was popular among the native population in many regions of Sumatra, especially on land which was less suitable for coffee. The rubber was generally planted one or two years after the coffee. After the fourth year growth was sufficiently closed to

make possible considerable economies in the weeding process. The attention given to each of the crops seemed largely dependent on the market situation, and the coffee was generally kept only during the first few years and abandoned after the sixth or seventh year when the yield had become small and the rubber started to produce (Huitema, 1935, p. 148).

Tergast (1930) gave a more general description of the native coffee planting industry in the various islands and recorded conditions comparable to those mentioned by Huitema. A more detailed description of the planting of C. arabica in Celebes, with excellent photographs, was published in 1927 (Paerels, 1927, and Gortmans, 1928). The methods were similar to those described for Sumatra. Catch crops were sometimes interplanted, with shade rarely provided. In some cases planting material was raised from branches of old trees placed nearly horizontally in the soil. A general description of the native coffee industry in Bali was published by Vink (1929) and it has remained one of the most important centers of native production of C. arabica in Indonesia.

CURING AND PRODUCTION

The native producers of Indonesia usually prepare their coffee for market by primitive methods, and the product contains a high per cent of dirt and black and broken beans. It was found that black beans were from premature harvesting. Huitema (1935, p. 212) worked on some of these problems, and recommended that native should store their product in sacks rather than in large heaps. Generally the curing was rather primitive. The most general method was to dry the picked berries in the sun. The dry pulp and skin, together with the parchment skin, were removed by pounding. Two men could clean two piculs of dried coffee per day (Bevolkingscultuur, 1926, p. 25).

The beans cannot be freed wholly of the silverskin by pounding. Only in the country of Arabia is the natural heat of the sun sufficient to loosen it. This process is called the "ordinary cure" or East Indian cure (Gewone Bereiding [G. B.] or Oest-Indische Bereiding [O. I. B.]). The cleaning, picking, and grading among the native peasants was not done as well as on the estates, and the results was that the market price was generally lower for the native product than for the same kind of coffee from estates. The "skinny" Robusta could be improved in appearance (van Setten, 1917, p. 171) by treating the beans for a moment in boiling water after they had been dried in the sun. They were removed quickly, and the water allowed only to penetrate the silverskin. The beans were then dried at once. After a few hours the silverskin could be removed easily. This process did not seem to find extensive application.

A special system, (Huitema, 1935, p. 161) for preparing Robusta for the market was used in the Lampong districts. The freshly picked berries were put in heaps or in boxes or barrels, and allowed to ferment for 10 to 15 days. By kneading or treading, the skin and the glucose layer was then removed and the parchment beans dried in the sun. Afterwards parchment was removed by pounding and winnowing. A very good coffee of a pleasing blue-green color and with very few black beans was obtained in this manner. A similar method was used for arabian in Mandheling and it yielded a fancy quality, the so-called Pakanten coffee (Loc. cit., p. 171). A system by which the berries of C. arabica were fermented for a few days and the beans then washed was reported for Java as early as about 1740 (van Stein Callenfels, 1916, p. 40).

Smaller centers of native coffee production outside of Sumatra are found in the eastern part of the archipelago. In Bali the crop which was mainly C. arabica was introduced in the beginning of the nineteenth century. These plantings had a more permanent character and were generally kept under shade, but other aspects of the technique were primitive. Old, run down fields were replanted or rejuvenated by stumping the old trees.

The best plantings were estimated to yield an average of 3 to 3.5 q./ha., with top yields of about double this. In 1925-1928 the export averaged about 2,000 tons per year (Tergast, 1930, p. 31).

In Celebes the southern Toradja region exported an average of about 560 tons per annum in the same period. Here too Arabica was planted on ladangs with rice and subsequently with potatoes, beans, and other food crops. Shade was rarely used according to Tergast (1930, p. 35). For a good planting the average yield per ha. was estimated at 600 kg., but this figure would seem to be too high. In Menado the production was mainly used for local consumption, and consisted mostly of Robusta.

IMPROVEMENT OF THE NATIVE PRODUCTION

A foreigner (C. Coleman 1931, 19p.) who visited Indonesia in 1930 and who had an open eye for the main problems of the coffee planting industry was struck by the apparent line of cleavage between the European and the Native coffee interests and by the fact that the former coffee interests were very much better served from a scientific standpoint than the natives. Coleman had stated that plans were proposed for the establishment of an experimental coffee plantation in Sumatra to work for the native coffee planters. His remark that it seemed doubtful whether this sta-

tion would be established in the near future unfortunately proved to be accurate.

There were many problems in connection with the native coffee planting industry which needed solution. Huitema (1935, p. 72) noted that the largest producing province secured millions of guilders annually for the native population from coffee. Establishment of a station to study the problem of the industry for the natives would have been fully justified.

The most important agricultural problems in connection with the native coffee planting industry were discussed by Huitema (1935, p. 172). A primary need had been improvement of the planting material, which is the best means for increasing productivity -- practically without applying any more labor, as Huitema rightly stated. At first the native used unimproved seeds. Later the Bangelan station sold seeds to them at a reduced price, and substantial quantities were used, especially on the west coast of Sumatra, (table in Huitema, 1935, p. 173). The Bangelan planting material had a very good reputation in the various coffee-producing provinces (Loc. cit., p. 144). Huitema recommended further experiments in selection for the benefit of the natives on the basis of the work at Bangelan, and advised that special attention be given to points such as resistance to diseases and pests, reaction in dry and wet years, resistance to weed growth, and general adaptability.

The whole problem of the available land, the temporary use of it, and the resting period required for restoring its fertility was discussed by Huitema (1935, p. 214) in a concise review of the usefulness of the forest on the mountain tops and slopes. He pointed out that water from forest-covered slopes was richer in mineral, that the water supply was more regular, and there was less danger of "banjirs" (flash floods). There is a far-reaching problem in the opening of forest land for native coffee plantings which are not laid out as a permanent cultivation and may easily become alang-grass plains after a few years, mainly as the result of grass and forest fires.

If the coffee plantings were more permanent, the same results would be obtained. One means for achieving permanency was the interplanting with shade trees. Other measures for improving the crop such as weeding, pruning, stumping, application of stable manures and chemical fertilizers, use of green manures, windbreaks, and measures against berry borer were discussed by Huitema (p. 193).

CHAPTER 7
LEAF DISEASE (HEMILEIA RUST)

GENERAL

Coffee is attacked by many diseases and pests. Of the fungoid conditions, "leaf disease" caused by Hemileia vastatrix is the most serious. For more than a century and a half, coffee in Indonesia was comparatively free from diseases and pests. Otherwise it would not have been able to produce the large crops of the early days when the technique of cultivation was still crude and the arabian type was grown in regions which offered far from optimum conditions. It is a striking fact that as soon as the rust appeared this situation changed. One serious pest and disease after another attacked the plantings, often with such severity that the whole industry was threatened. Some important insects and other pests were introduced after the appearance of Hemileia. At first there was no causal connection with them and that rust. In other cases, however, leaf disease may have weakened the coffee trees to such a degree as to make them easier victims of a new parasite.

Hemileia spread all over Indonesia about 1880. Ten years later the green-scale, Lecanium viride, became a serious danger. About the year 1900, nematodes attracted the attention of research workers, for they were killing whole groups of trees and were causing planters to doubt whether coffee could still be profitably produced. Then in 1907 the branch borer, Xylosandrus, appeared. This pest gradually spread all over Java. About 1915 the berry borer (Stephanoderes hampei), already known for some time, suddenly became a serious pest, and within a few years it was found all over Indonesia. At first it was believed that it could mean the end of coffee production. Dieback of the top from attack by a Rhizoctonia already known for some time in Sumatra, was found about 1930 in east Java where it attacked a high percentage of the trees on occasions.

HISTORY

Hemileia rust is caused by a fungus belonging to the Uredineae named Hemileia vastatrix B. et Br., which attacks the leaves and forms orange-yellow spots on their under side. The disease was first discovered in Ceylon about June 1, 1869 in Madulsima (Marshall Ward, Third report, 1882, p. 253), and was first described by Berkely and Broome in 1869. On p. 93 Hemileia canthii and H. vastatrix are mentioned on Canthium campanulatum (March 6, 1868). Its first appearance in Indonesia was recorded in 1876. In August 1876 the director of the Botanical Garden in Buitensorg received suspected leaves from Sumatra (Verslag von s'Lands Plantentuin, 1877, p. 31). Scheffer found Hemileia on them and described the fungus in 1878. He used a plate reproduced from Berkeley and Broome. (Enumeration, 1873, Tab. 3).

The life history of this Hemileia has been described by various authors. One of the first reports of it as a fungoid growth dates from 1879 (Morris, 1879; p. 11). A full description in Ceylon was published by Marshall Ward (1882a, p. 299). Its early history, and experiments in combating it, were recorded in 1880 (Thiselton Dyer, 1880, p. 119). Burck (1889, p. 9 and 1889, p. 1) recorded the life history of Hemileia in Java. Another description, in which a few points of minor importance in Burck's description are corrected, was published by Zimmermann (Meded. s'Lands Plantentuin no. 67, 1904b, p. 27). A very complete description with good bibliography was compiled by Delacroix (1900, p. 14), and it also contained some articles on Hemileia from the Gardener's Chronicle. A good review of the history of Hemileia was published later by the same author (1911, p. 279).

As Ultee (1934b, p. 349) explained, there was a difference of opinion as to how far the ruin of Arabica planting was caused by leaf disease. That this was the real cause is now well proven, for it is impossible today to establish an arabian planting in the low country, in Java, even on the best soil and with the best care. This was quite possible before Hemileia appeared in Java.

In the work of Bally (1931, p. 123) may be found a good list of the literature on Hemileia. Taking into account the very rapid multiplication of the fungus by spores (Marshall Ward, Third Report, 1881, p. 6) and their quick spread by wind (ibid, p. 9), it is not surprising that soon after its discovery in Sumatra the disease spread all over Indonesia. In 1879 it appeared in the Cultuurtuin in Bogor, according to a report of the director. A rather serious attack on new coffees was observed on both C. mauritiana and C. mokka. Other kinds were attacked less heavily, but only C. liberica showed no symptoms of the disease. The estates in the neighbourhood were also found to be infected (Anon, 1879, p. 188). In 1882 the disease was observed in east Java and in 1883 and 1884 tens of thousands of trees there were killed (Morren, 1896, p. 155).

At this time W. Burck (1887 and 1889) made an extensive study of the leaf disease in Java. The low yield of the government plantings since 1884 to 1888 were attributed by him mainly to leaf disease, since the producing area was not materially reduced (1896a, p. 363).

How the disease originated in Ceylon has never been definitely ascertained. Hemileia vastatrix had been found on leaves of C. arabica in German East Africa as early as 1885. It had been

suggested (Anon, 1913, p. 169) that this rust was of African origin. In the Buganda Kingdom in Central Africa all the indigenous coffees were found covered with H. vastatrix. Although the native trees were attacked heavily by Hemileia, it did not affect them seriously, a fact which lent further support to the view that in Central Africa it was endemic rather than an introduced disease. Its virulence in Ceylon could possibly be explained by the assumption that the disease was not native to the island but, that under the new conditions the introduced fungus assumed epidemic proportions (loc. cit., p. 169, see the note). The article did not indicate whether Hemileia was present in Africa before it was observed in Ceylon. Available information about its adaptation from one coffee species to another supports the theory of Marshall Ward (1881, p. 24) who made a thorough study of the disease and he concluded that it accumulated slowly on C. arabica by passage from some jungle plant. It was found on a native wild coffee, C. travancorensis, and his reciprocal infection experiments with C. arabica succeeded. He concluded that this rust probably lurked in the jungle long before C. arabica was widely planted on estates in Ceylon. He also studied a rust found on such a widespread plant as Canthium campanulatum and decided that it was not sufficiently different to warrant its being considered a separate species. Infection of Canthium with Hemileia spores from coffee caused the germinal tubes to begin to form a normal mycelium in the leaf as in coffee. Hemileia canthii was also studied. It did not attack coffee. The mycelial branches fused into a cellular body, as in H. vastatrix, as they formed the spore bearing head.

It may be noted here that Burck (1889, p. 25) found Hemileia on C. bengalensis. Cramer (1908b, p. 311) observed it on this species and on C. madurensis in the Cultuurtuin in Buitenzorg. Both species are closely allied with C. travancorensis from Ceylon. In another jungle plant in Ceylon, Canthium campanulatum, Thwaites found a Hemileia in 1868 which Marshall Ward considered probably identical with H. vastatrix. It seemed possible that Hemileia had become a parasite of coffee by adaptation of a form originally occurring on wild plants.

It has been thought that the appearance of Hemileia in east Asia was connected with the introduction of Liberica coffee from Africa, but two facts cast doubt on this assertion. H. vastatrix was first found in Ceylon, attacking C. arabica on June 1, 1869 (Marshall Ward, 1881, p. 27), and C. liberica was not introduced into Ceylon until 1873 (Wigman, 1888, p. 5). Furthermore, Hemileia was first noticed in Indonesia in August 1876, in Sumatra, some time before C. liberica could have been planted there. In 1876 there were a few newly acquired one-year-old Liberica plants in the Cultuurtuin in Buitenzorg. If they had carried Hemileia, this situation would certainly not have escaped the trained eyes of botanists of the s'Lands Plantentuin, for they watched carefully for just such unwelcome guests.

In 1930 the question of the origin of the leaf disease came up again. We have already noted that Marshall Ward believed that Hemileia was an obscure fungus eking out a precarious existence on C. travancorensis (or on Canthium) until the vast extension of C. arabica in Ceylon offered it an unlimited food supply which it attacked at once. However, several considerations weigh heavily against this view, the chief being that coffee had been the staple crop in Ceylon for over 30 years when Hemileia first made its appearance on the island. If Hemileia was indigenous to Ceylon, it is difficult to understand why its appearance in coffee cultivation was delayed so long. The modern view set forth by Butler, Director of the Imperial Bureau of Mycology at Key, is that it is reasonable to suppose that Hemileia originated in Africa, spread with living plants through human agency from one district to another, and ultimately crossed the ocean to Ceylon. There seems little doubt now that Hemileia is native to Africa.

The work of Wilson Mayne (1936 et seq.) at Balehornmur on the various strains of H. vastatrix with different attacking power, seems to confirm Marshall Ward's original view of increased virulence out of fungus variation. The Hemileia fungus brought over from Africa to Ceylon may have found there a fertile field and entirely different external conditions, and it could have developed in Ceylon new strains of much greater virulence than the original strains in Africa. There it may have become more dangerous and more disastrous to the C. arabica in higher altitudes than the home strain was to the home C. arabica.

The disastrous effects of Hemileia on the coffee planting industry in Ceylon are well known. The damage done by the disease there has been estimated at 260 million guilders (see Ultee, 1926a, p. 628). The disease ruined the industry, but the planters were fortunate enough to find other profitable crops, tea and rubber, to replace the disappearing arabian coffee. How rapidly this took place is obvious from contemporary reports. Ceylon's coffee production decreased (Indische Mercur, 1888, p. 563, and 1890, p. 73) in 1869-1878 by more than 75 per cent, while by 1890 nearly 90 per cent of the area planted in coffee was reported to have been abandoned.

The flourishing state of the coffee planting industry in Ceylon in the days when rust made its first appearance on the coffee there can be seen in the figures published by van den Berg (1879, p. 453): In 1869 the area of estate coffee was 160,000 acres, and it was increased to 215,000 acres

in 1876. Nevertheless, the crop decreased as a result of the depredations of the leaf disease. The disease wiped out C. arabica in the lowlands where conditions were not favorable. In 1868-1870 exports amounted to over a million cwt. per annum, but in 1893 it was only 6.7 per cent of this figure. During the same period the land planted in coffee had dropped from 275,000 acres to 35,000 acres (Ind. Mercur, 1893, p. 562). Production of coffee in Indonesia was maintained by replacing C. arabica with varieties more suitable for the lower altitudes and by improving the planting material in the higher coffee belt.

HEMILEIA ON C. ARABICA

In Indonesia Arabian coffee, if not grown under optimum conditions, was severely attacked. In the middle belt, at 300-800 m., trees might become practically leafless after a heavy crop, but they would recover and might still produce profitable crops in a few years with favorable weather conditions. In the higher altitudes the attacks were not so severe, but trees were never absolutely disease-free. Hemileia still causes an annual loss of a certain percentage of the crop there. In the early nineties coffee plantings were still being rapidly extended, and the industry was highly profitable, a fact revealed by figures cited in the Ind. Mercur of 1893 (p. 275) and by Vogler (1900-1901; p. 729). The figures for the total coffee crops of Java estates reveal that in those days the estates of the middle belt, many of which were established after the appearance of Hemileia in Java, still contributed fair though variable annual crops to the export trade before C. arabica was pushed out of this belt by Robusta during the period from 1905 to 1915.

In British India the reverse process seemed to be observed (Butler, 1918, p. 113). Coffee leaf disease appears to have lost a good deal of its virulence since the bad years that followed its first appearance in Ceylon in 1869. It is difficult in these cases to separate the factors which alter the resistance of the host plant from those that effect the parasite, but it seems probably that alterations in the innate virulence of the latter are responsible for the changes observed. In this connection it might be noted that the coffee planters in east Africa did not consider Hemileia a very serious pest for C. arabica, although it appeared everywhere in African plantings. It was serious only when some unfavorable factor affected the Arabian coffee. (Francois, 1931, p. 77). It may be that C. arabica finds nearly optimum conditions in east Africa and that this factor is responsible for the resistance of the coffee there.

In India the study of the virulence of leaf disease on C. arabica was taken up by the Department of Agriculture of the State of Mysore. Physiological strains of the fungus with different capacities for infecting different varieties of coffee were distinguished. This point was mentioned as early as 1932 in a preliminary note (Anon. b. 1932); and subsequently more data were published. At least three strains existed, but plants were found which resisted all three. The resistance to Hemileia was complicated (Wilson Mayne, 1936, p. 3, 1939-40, and 1940-41). Two families showed immunity to strains I and II, but were susceptible to strains III and IV. The relative scarcity of these latter strains permitted these families of plants to show a substantial resistance to the disease but some infections did occur. Wilson Mayne also did a considerable amount of field work which tended to confirm the laboratory studies.

LEAF DISEASE ON C. LIBERICA

Soon after the appearance in Indonesia of Hemileia on C. arabica, it was also noticed on C. liberica. In reply to questions (see Questions-Liberian coffee, 1876, p. 3) it was stated that in the previous year some of the trees on plantations in the country of Liberia were affected with what was said to be H. vastatrix. However, further descriptions of the condition indicated that it was leaves, that had turned yellow, much as they did from want of cultivation.

In 1881 (Jaarverslag, 1881, p. 22) Hemileia was reported to have caused a mild attack on some of the Liberian trees in Indonesia. In 1882 no leaf disease was observed on the Liberian coffee (Verslag van s'Lands Plantentuin, 1882, p. 22). In 1884 the report mentions that both plantings of Liberian coffee developed well, but a few trees suffered slightly from Hemileia (Verslag, 1885, p. 20). In 1887 it was reported again to have attacked that coffee (Heffer, 1887, p. 460). In 1888 the introduced trees in the Cultuurtuin station were described as "about ten years old, but as vigorous as ever", and the yield was estimated at 15 to 20 piculs per bahoe (13 q. to 17.5 q./ha.). The report stated that a great advantage of Liberian coffee over the common Java coffee was that it was more resistant to leaf disease. It was attacked, but the diseased plants recovered quickly (Wigman, 1888, p. 8). In 1879 C. liberica was described as showing leaf disease occasionally, "however not to such an extent that with rational methods of cultivation we would feel doubtful about its future" (van Romburgh and Wigman, 1896, p. 552). At that time the original trees, introduced in 1875 and thus about 20 years old, still looked healthy, but a decade later they were described as being leafless from leaf disease (Cramer, 1908b, p. 67). As late as 1917 three of these original

trees were still alive. They were then 41 years old, and it was evident that they were no longer vigorous, beautiful trees (van Hall and van Helten, 1917, p. 41). They were still used for grafting, and grafts from one of them still in the clone collection of the Cultuurtuin, were fairly Hemileia-resistant.

Reports from Ceylon on the introduction of Liberian coffee there are similar. Of 24 plants received from Kew in a Wardian case, 4 when planted became infected and were so severely attacked by leaf disease that they died. The others suffered but ultimately recovered. Many of the latter, however, were weakened by the disease (Thurber, 1881, p. 113). In an interesting series of reports on Gemampir, van Delden (1886, p. 324) described the growth of C. liberica on this estate from 1880 on. As early as 1883 some leaves of 2 and 3 year old plants were attacked by Hemileia, but the stems did not suffer seriously and continued to grow vigorously (p. 332).

C. liberica and C. arabica would seem to have been attacked in different ways. In the case of Arabica, either the entire field became leafless or the attack was uniform light, with Liberica there were great individual differences in the severity of the attack on individual trees. With a light attack there was a small number of badly affected trees, and when the attack was heavy, nearly all the trees were thin in leaf, but here and there one could still find a tree with fully intact foliage, producing well. In a young planting a certain percentage of plants was attacked quite early, and the number increased every year. When the field was 12 or 15 years old, the majority of the trees had become valueless (Cramer, 1907, p. 720; photograph in Cramer, Variabiliteit, 1913, p. 9, Fig. 1).

As early as 1893 (see Indische Mercur, 1893, p. 418) attention was drawn to the individual differences in the degree to which trees were attacked by leaf disease and seed selection was recommended to increase Hemileia resistance. According to observations in 1894 by Pelle, a planter in Palembang, Hemileia singled out a certain type of Liberian coffee with large thick leaves for attack, but at that time the cases were only sporadic. Healthy trees were found side by side with heavily attacked trees. Leaf disease occurred only during the rainy season and then only slightly; and it caused only a very slight reduction of the crop.

Zimmermann (1904, p. 32) observed the different ways in which C. liberica and C. arabica were attacked, but he could never ascertain whether C. arabica trees showed a difference in their susceptibility to leaf disease. On the other hand, he noted great individual differences in C. liberica. It was generally true that in a group of trees nearly free from leaf disease some individuals could be found of which nearly every leaf showed numerous lesions with large quantities of Hemileia spores, or which had already lost most of their leaves. Such trees generally died after a while.

In the case of C. liberica the rust attacked not only the leaves, but also the green bark of the young branches and the top of the tree. The characteristic hyphae and haustoria of H. vastatrix could sometimes be found in the green fruit (Zimmermann, 1904, p. 71). In 1906 an east Java planter noted a large scale attack on the berries in his fields (Lansing, 1907, p. 195). It might be thought that this indicated a further increase of the virulence of the disease, but such diseased fruits were found on trees with healthy foliage. One of the clones in the Cultuurtuin regularly showed a high percentage of rust-attacked fruits, even though it was one of the clones, number H. I., with the most resistant foliage.

Although the problem was not too serious in the case of C. liberica in 1897, it soon became worse. There were more and more complaints from planters about the impossibility of establishing productive plantings of Liberica. It was attributed to a gradual loss of resistance in the species, to "degenerations" as planters called it, and they urged a renewed introduction of seeds from the country of Liberia to put "new blood" into the variety. The degeneration was attributed to lack of selection, for in the first years after the introduction planters would take any seed obtainable (Anonymous, 1905, pp. 44, 47, 123-175). According to "d. B." there was no doubt that the trees raised from the original seed grew and yielded better than those grown from seed produced in Java. He felt that this degeneration was the consequence of the change in natural conditions, and perhaps the enemies of the plant also had some influence. It was argued that the new seeds should be taken from wild trees, after identifying the best ones. The General Coffee Syndicate, the producers' organization, was willing to share the cost of shipping seeds from Liberia to Amsterdam, raising the plants there, and then shipping them to Java (Anon. 1905, p. 175).

In March 1908 a Java planter, S. Soeters, went to Monrovia and brought seed back (Cramer, 1913, p. 328). Soeters himself had collected the seed, and in September 1908 they were set out in Java on several estates. Cramer introduced seed from other places where C. liberica had shown no signs of degeneration, viz., Dutch Guiana, where Hemileia is not present. The seed that Soeters brought from Liberia which is free from Hemileia, were planted in Bangelan, and they produced plants afflicted by leaf disease as heavily as from domestic seed (Jaarverslag, 1908, p. 88). The seedlings grown from the seed from Dutch Guiana (Cramer, 1907a, p. 712, 718, 719) suffered from heavy

attacks of leaf disease in the nursery, often to such an extent that it was deemed necessary to remove them, since they threatened to infect neighboring liberian plants from domestic seed. Among the seedlings raised from seed of rust free coffee from Liberia and from Nigeria, no thrifty plants were found when grown in severely infested Bangelan (Verslag Bangelan, 1909, p. 189). On the other hand, seed from the so-called degenerated C. liberica in Java were sent to Dutch Guiana, where Hemileia does not exist and external conditions are very favorable for this coffee, and they produced excellent plantings with no sign of deteriorations (Cramer 1927, p. 136).

I concluded from such facts as these that if the equilibrium between the plant and the fungus had been broken in favor of the latter, it was not because the coffee had become weaker, but because the fungus had become stronger and had adapted itself to the new coffee. This conception of the problem was shared by Quanjer, who thought that the increased susceptibility of Liberian coffee to Hemileia perhaps had to be attributed to the sudden appearance of a variety with altered virulence (Quanjer, Thung, and Else, 1928/29, p. 631). As one of the means of overcoming this increased virulence (see Cramer, 1910, p. 380) it was considered advisable to begin the selective breeding of more resistant strains of Liberica, and I later demonstrated that by using seed from healthy trees in very badly affected fields, that it was possible to make productive plantings of good appearance, as was reported by Fröhwrith (1923, p. 160) and Cramer (1913, p. 97, fig. 10a). It was noted that certain mother trees produced seedlings so heavily attacked by leaf disease that they were worthless. Other trees yielded seedlings practically free from the disease (Cramer, *ibid.*, p. 106; Table 32 and photograph 10, p. 79). Continuous selection later provided healthy clones of C. liberica.

Years ago de Wildeman (1910, p. 355) doubted that a renewed introduction of seed of C. liberica would help against leaf disease. He raised the question of a possible connection between the presence of domatia and resistance to Hemileia. He suggested a study of the organisms finding a shelter in these domatia, since they might clean the leaves of rust spores. He added that if his supposition were right, it would be useful to introduce the inhabitants of the domatia from Liberia into Indonesia together with the seed. Thiselton Dyer's (1880, p. 121) mention of the larva of a small undescribed dipterous insect which fed on ripe sporangia might be pertinent here.

In later years C. liberica was introduced into Java from Africa on several occasions. None of these plantings proved to be Hemileia-resistant. As soon as two years after planting, some were heavily attacked by leaf disease (van Hall & van Helten, 1917, p. 40). According to Lepplae (1936, p. 48) the liberoid species also suffer from leaf disease in Belgian Congo. It appeared there in 1913 on the Lula plantations, where the liberoid kinds proved the most susceptible.

These facts indicated (Cramer, 1907, p. 725) that selection might provide a variety with regular, moderate production, and that it might be possible to counteract increase in virulence by increasing the resistance of the coffee trees in similar measure, particularly by grafting.

In 1905-1910 several coffee species, closely allied to C. liberica, were introduced into Java, and all proved susceptible to Hemileia, although less than C. liberica itself. C. excelsa, one of the most valuable kinds, suffered severely from Hemileia; but the plants recovered (Cramer, Verslag botanist, 1908b, p. 67) and only those which flowered earliest remained infested (Cramer, Excelsa-koffie, 1908, p. 602). Some of the strains planted, Bgn. 121, the derived seedlings, and Bgn. 121.04, seemed quite resistant, although not immune. The same could be said of C. abeokutae, very closely allied to C. liberica (Cramer, 1913, p. 422). Its first generation in Java also seemed less susceptible than C. liberica (Cramer, 1909a, p. 475).

LEAF DISEASE ON C. ROBUSTA AND OTHER SPECIES

Robusta proved to be resistant from the beginning, although not immune. It is at home in the middle belt where it apparently finds optimum conditions. A slight amount of Hemileia on C. robusta and some of the allied species had been observed from the beginning. At the Coffee Conference in Soerabaja in 1907 van Lennep (1907, p. 698) mentioned its occurrence on weak Robusta trees, but the thought was that, generally speaking, the disease did no serious damage to trees recently introduced. Wurth (1908a) also noted substantially greater resistance. He stated that at that time Robusta did not suffer from Hemileia at all or suffered so little that it was of no importance in production. Cramer (1907b, p. 131) stated on the same occasion that leaf disease might be observed on Robusta in nurseries and in young plantings. This observation led to the warning that in a few decades the new species might be pushed back to the regions where it found optimum conditions. David (1928, p. 46) noted that in the Philippine Islands Robusta was found to be susceptible to Hemileia. When C. robusta and other species were grown there, side by side, the Arabian coffee succumbed first. Robusta seemed to be intermediate between C. arabica and C. liberica, in its susceptibility to H. vastatrix.

There may have been a tendency in Indonesia for the disease to increase in virulence. Wurth (1912, p. 10) stated that "The leaf disease has increased greatly in Robusta; but it is not the re-

sult of degeneration of the Robusta, rather of the adaptation of Hemileia to the new host plant". In an earlier publication, Wurth (1909-1910, p. 3) had cited the fact that an old Liberian plant in a bad state, if stumped, would give shoots on which hybrid grafts would thrive well. He added that this fact was the most convincing proof that the deterioration was due not to degeneration but to Hemileia's adaptation to C. liberica.

Luckily, although Robusta might not be immune, there was no evidence that Hemileia had increased its attacks on the species. Although unimportant outbreaks of the disease on Robusta were recorded from times to times from the Malang Institute, Hemileia never was a factor of great importance (Pfältzer, 1936, p. 988). The closely allied species also have been observed in this connection. In 1906 it was found that C. canephora was much more susceptible than C. robusta, and this was frequently confirmed. Even information from Madagascar pointed to this great susceptibility (Cramer 1909; p. 79).

In 1911, Wurth (p. 13) mentioned that some plantings of C. canephora were very susceptible to Hemileia, while others suffered hardly at all. The greater susceptibility of C. canephora seemed to be hereditary. A well known case was of "Robusta S.S. 24", which showed a brown tint in the green berry indicating that there were some strains of C. canephora in this type. Some of its seedlings also resembled C. canephora. According to Hille Ris Lambers both mother tree and clone, were regularly attacked by Hemileia (cited by Bally, 1931, p. 135).

A case occurred in which a C. canephora tree, standing in a field with Robusta, was badly infected by Hemileia and spread this infection to the surrounding trees and had to be cut (Landbouweekblad, 1916, p. 16). C. uganda is one of the less susceptible robustoid species, but in a nursery where it stood next to diseased C. canephora it was infected (Cramer, 1908b, p. 68). A case like this shows how Hemileia may creep in and establish itself on a resistant species.

Coffea stenophylla has never suffered a bad attack of leaf disease in the Cultuurtuin. The first plant was introduced from Kew Gardens in 1896 and developed some Hemileia when planted (van Romburgh, 1901, p. 608). C. congensis remained practically free from leaf disease (Cramer, 1909, p. 77). Two totally different kinds of coffee, C. schumanniana and C. perrieri, also seemed to be virtually free from leaf disease.

HEMILEIA ON COFFEE HYBRIDS

In addition to improving disease resistance by seed selection and by the introduction of more resistant species, there is still a third device for combatting Hemileia. This is the use of hybrids with increased resistance, such as the "Arabica-Liberica hybrid" from Kalimas (Cramer, 1910, p. 380), which is more resistant than either of its parents. The reciprocal hybrid Liberica-Arabica and similar combinations such as QP. (Robusta x Excelsa) have also shown great resistance although they are not absolutely immune.

The first report on the Kalimas hybrid mentions its resistance to Hemileia (Hybride, 1893b, p. 215). Kramers (1898, p. 90) after a visit to the region in 1897, mentioned the Kalimas hybrid and stated that while Arabica and Liberica were both heavily attacked by leaf disease, he saw no spot on the Kalimas hybrid's leaves. Kalimas branch grafts remained practically free from Hemileia, while the C. liberica next to them suffered (V., 1897, p. 529). All reports on the grafts of the Kalimas hybrid confirm this, e.g., a report of 1896 (cited by Ottolander, 1936, p. 360), and a report on the then nine-years-old grafts at Klein-Getas (Hybriden-enten, 1897a, p. 95).

However, the original hybrid tree at Kalimas which acquired the reputation of being free from Hemileia early as 1890 and gave a high yield in 1898, suffered heavily in the beginning of July 1898 (Kramers, 1899a, p. 96). This was in accordance with the general theory that a highly productive tree is much more susceptible to leaf disease and parasite infection. In 1899 van Riemsdijk remarked that all heavy yielding hybrids suffered from the great enemy, leaf disease (du Bois, 1900-1901, p. 534).

When van Riemsdijk planted his first grafts in the eighties, he observed that top grafts of the Kalimas hybrids were much more susceptible to leaf disease than branch grafts, and this was confirmed at Bangelan. Suckers from the original tree at Kalimas were brought by Cramer (1934, p. 201) to make top grafts at Bangelan. They suffered more from leaf disease than did branch grafts. According to an oral communication of Hille Ris Lambers to Honing (1928-1929, p. 27) the former found that orthotropic branches of good yielders gave grafts which more sensitive to Hemileia than grafts from side branches of the same tree. The grafts of Kawiseri and QP. hybrids were practically free from Hemileia. The Soember Sengkareng hybrid sometimes suffered from it (Ultee, 1922, p. 19).

Another group of hybrids, some of which showed a great resistance to leaf disease, were the C. congensis hybrids with C. robusta grouped together as "congusta" or "conuga". The parent C. congensis should itself always to be practically free from leaf disease. C. congensis var. chalotii, really a hybrid of C. congensis with C. canephora, inherited the same great resistance. It proved

very resistant in Madagascar. In a region where Hemileia destroyed the C. arabica rapidly and did a great deal of harm to the C. liberica, it was completely immune. Occasionally a spot of Hemileia has been seen on a "chalotti" tree, but the disease did not spread on it (Fauchere, 1910, p. 1). Some of the hybrids of C. ugandae x C. congensis, however, sometimes suffered from Hemileia, for example the clone Congusta 2.C8.

CHAPTER 8
OTHER FUNGOID DISEASES

Hemileia has been a dominating factor in world coffee production since its first appearance about 1870, but there are a few other cryptogamic enemies which deserve mention, even though they are only of local or temporary significance.

DISEASES OF THE LEAVES

There is a series of Fungi which attack the leaves and cause spots on them. They are generally brown or black, and visible on the upper side. Cercospora coffeicola Berk. et Cooke, is found in all coffee-growing countries of the world (Bally, 1931, p. 151; Zimmermann, 1904, p. 88, both with bibliography) and sometimes does damage in nurseries. Occasionally it is also found on berries and is noxious. Gloeosporium coffeanum Del., Colletotrichum incarnatum Zimm., Phyllosticta spp., are also the cause of leaf spots, generally under excessively moist conditions (Bally, loc. cit; Vraagbaak, 1941, p. 201-203). Rhizoctonia spp. (Reydon, 1933, p. 758) appears in the rainy months as well as in the middle of the dry season, a circumstance that may be attributed to the fact that the temperature is an important factor in the growth of this fungus. It is considered of little economic importance. It is, of course, a different Rhizoctonia from the one causing top-disease. When these pests occur in nurseries, it is recommended that shade be reduced by removal of some of the roofing, that Bordeaux mixture be applied, and that other related measures be adopted (Vraagbaak, 1941, p. 203).

Cephalosporium coffeae Went, one of the Algae, lives on the leaves, but in Indonesia it does little harm. However, it attacks unripe berries at times and makes them dry up (Bally, 1931, p. 157). The sooty mould or black fungus, Capnodium javanicum, develops on the secretions of scale insects. The cobweb-disease forms threads of mycelium extending over the leaves (Zimmermann, 1904, p. 46; Bally, Handboek, 1931, p. 98). Not any of these fungi are a serious threat to coffee production.

CORTICIUM

Djancor oepas or pink disease, Corticium salmonicolor B. et Br., occurs on the branches. The coffee fruits are covered on their undersides with an orange-pink or whitish crust (Bally, Handboek, 1931, p. 101; Vraagbaak, 1941, p. 185). In the early cobweb and knobby-form stages it is not easy to recognise. The fungus occurs on numerous other tropical tree crops such as Hevea, Cinchona, Citrus, etc. Its appearance on Cinchona was studied in detail by Rant (1911, no. 13, p. 18). He succeeded in infecting Cinchona plants with spores from C. arabica and studied the whole course of the infection closely. The affected parts should be cut or burned after covering them with a 5 per cent solution of tar carbolineum or Bordeaux mixture (Vraagbaak, 1941, p. 187) in order to prevent its spread. It is best to take these measures in the beginning of the dry season. Attention should also be given to the early stages of the disease.

Bally (1931, p. 109) emphasized the effectiveness of the treatment with Bordeaux mixture if applied at the right time. The cost depends, of course, on the number of attacked trees per ha., it is mainly for labor, and it was found to vary from f 1.00 to f 8.50. The disease does not only occur in moist, densely shaded fields, for Bally (1931, p. 755) found it in fields where the shade had been removed. Perhaps pruning, as suggested by Rant (1911, p. 34) for Cinchona, might be beneficial inasmuch as it would open the body of the tree to air.

Some bushy green manures such as Tephrosia and trees like Hevea, which are often grown with coffee may also be attacked and spread the infection. It may sometimes do considerable harm, especially in wet climates and among densely branched varieties of coffee. Van Hall and van Helten (1917, pp. 18, 19, 32, 33) mention heavy attacks by pink disease on several coffee species such as C. arnoldiana, C. aravimniensis, and C. excelsa.

RHIZOCTONIA TOP-DISEASE

This disease well known in Indonesia, is caused by a fungus, Rhizoctonia spp., which attacks the stem and branches of the tree and causes asymmetrical development of the branches. Its hyphae penetrate into the wood vessels. An excellent and well illustrated description was published by Bally (1931, p. 66).

The disease was first discovered in 1926 in southern Sumatra and studied there by Bally (1926a, p. 979). Probably it had been present there since at least 1921 (Muller, 1936, p. 341). Originally there was some uncertainty as to whether dieback of old trees in Sumatra was identical with top-disease of young trees, but in 1929 Muller (1929, p. 167) identified it as the same disease. How serious the disease can be is well demonstrated by a case described by Bally (1931, p. 77) in which the percentage of infected trees in a field increased from 69 per cent to 85 per cent in one year.

The disease caused a considerable crop loss, calculated for three separate cases by Muller (1936, p. 329) at 16.4, 50.5, and 28.8 per cent of fruit. Muller (1930a, p. 29) tried to find out whether the top disease was related to the Daikuhara, the hydrolytic acidity and the hydrogen-ion-concentration of the soil, but he concluded there was no direct relationship.

After experiments with Bordeaux mixture and similar products Muller (1935, p. 38) concluded that they are not definitive counteragents of the disease. Countermeasures consisted in recognizing and pruning and burning the early infected branches and tops. Muller (1936, p. 279) found that it was possible to recognize the first infections as the leaves of the first infected branches grew abnormally erect. The pruning should be deep enough to remove all the infected wood. In an experiment with the early removal and burning of all suspect branches the infection was reduced by 25 per cent (Muller, 1936, p. 335). This was important, since the fungus entered the leaves and from them grew into the wood vessels of the branches and the stem. It was recommended that if the whole top was infected, the stem was to be cut back below the visibly diseased parts.

Observations of the health of shoots from *Rhizoctonia* diseased trees showed that about 35 per cent of the shoots were infected by hyphae growing from the stem into the wood. Countermeasures involved alertness for early cases of the disease, cutting the infected parts away and burning them. It was important to give special attention to young trees, in which the regenerative power is greater than in old trees. In pruning them two or three apparently healthy internodes were also be removed below obviously diseased parts. Often healthy shoots developed but in old trees the stem was frequently infected all through, no longer capable of developing healthy shoots (Rudin, 1937, p. 289). Often young trees showed only one diseased branch, but there was danger that the fungus had already penetrated the stem. Pfältzer (1937, p. 1395) recommended more severe pruning.

In 1928 Java was thought to be free from the disease, although there had been some suspicious cases. A close study verified the suspicion, but it was not the serious form of the disease found in southern Sumatra (Bally, 1928a, p. 980). Shortly afterwards it was found on an estate on the Kloet mountain (Ultee, 1928a, p. 1290). In 1930 Besuki was still free from the disease. Only one estate in central Java was infested, but in the Malang and Kediri provinces it was spreading. In southern Sumatra dieback occurred generally. Neither was eastern Sumatra free from this disease (Overzicht, 1930a, p. 433). In 1935 de Fluiter (1935, p. 1024) reported that the disease had also appeared in the Besuki province on the slopes of the Yang mountain, and it was found on an estate in Celebes in February 1931. Since then the disease was reported as spreading (Pfältzer, 1940, p. 228), but countermeasures have yielded good results. Species or varieties of coffee immune from the disease have never been found. The list (Muller, 1936, p. 341) in which the various susceptible kinds were enumerated included forms of *C. robusta* and *C. liberica*. Arabian seemed to be less susceptible. On estates where 80 per cent of Robusta was attacked, it was found on only 12 per cent of Arabian. In both Java and Sumatra it was very susceptible. Snoop (1941a, p. 408) reported that individual offspring from Robusta mother trees, dating from plantings in 1925 and 1927, were inspected in March 1929 and showed for the former planting, 63.3 to 75.9 per cent. In 1930 a second inspection was made, and again no marked differences between the individual offspring were detected. All plots showed infection of over 90 per cent. The Congusta hybrids seemed to be attacked only slightly.

ROOT DISEASES

Several fungi were found to attack the coffee root but up to 1931 none was of great economic importance (Bally, 1931). By far the most frequent was the brown fungus of coffee, *Fomes lamagensis* Murr. Together with mycelium and soil particles it was found as a thick crust around the attacked roots. The fungus infects many other trees, such as Hevea, shade trees like Albizzia, and an *Artocarpus* that is a jungle tree. The fructifications were never found on coffee, but Bally was successful in obtaining a small one by exposing trees to the air and rain. In Vraagbaak (1941, p. 171) the fungus has been mentioned as *Fomes noxius* Corner. The nomenclature is explained by Pfältzer (1935, p. 850). When the disease is first notable it is in a well advanced condition, and the only measure which can be taken is to dig it out and burn. If all diseased roots in the soil are destroyed, and a new seedling planted it will remain healthy. Generally the fungus does not kill large numbers of trees because it grows slowly and generally attacks the tap root, not the thinner rootlets. In openings of jungle, where *Artocarpus* was frequent, the disease was found to cause considerable loss in young coffee plantings. This could be avoided by identifying these trees in the jungle and cutting them out at least one year before planting coffee.

There are several other fungi: *Rosellinia*, *Xylaria*, *Helicobasidium*, which attack the roots of coffee in Indonesia. Various fungi attacking the coffee root have been enumerated by Steinmann (1925, p. 79). Bally described the black root fungus as *Rosellinia bunodes* (1930, p. 1). Pfältzer and de Fluiter (1941, p. 121) studied *Polyperus coffeae* Wakaf., a fungus found on roots infected by the root mealy bugs, *Pseudococcus deceptor* Gr., and living in symbiosis with this insect.

CHAPTER 9
PESTS OF COFFEE

NEMATODES

Among the pests that were not fungi, attacking coffee in Java, the most destructive have been nematodes or eelworms, which live in the root system and kill the trees. Whole groups of trees often die when nematodes are frequent, and their attack has been classed as next to Leaf Disease in importance (Cramer, 1913). Arabian coffee can recover from the Hemileia, whereas trees attacked by nematodes yield no fruit, decline, and ultimately die. Nematodes are common in the soil but only a few species are parasitic. Of special importance were two of them in Indonesia, first Tylenchus coffeae, with its new designation of Anguillulina pratensis Goffart, and second Tylenchus similis, formerly T. acutocaudatus, now Anguillulina similis Goodey. Heterodera marioni Goodey, also called Cacconema radicolica Greef, was less frequent and not so dangerous, and it appears to have done most of its damage in nurseries, especially on land where tobacco had been grown (Vraagbaak, 1941, p. 251).

Anonymous (1890b, p. 146) stated that Heterodera also had been found on trees in old coffee plantations. This was confirmed later by Cramer (1908b, p. 11) who stated that Heterodera was found in one sample of roots of C. arabica and one of C. robusta. This nematode caused roots to form knobs or galls in which the female lives. Care must be exercised in the diagnosis. Similar malformations, called pseudogalls, of the roots of plants in the nursery may be caused by too high a concentration of the soil salts (de Fluiter, 1936b, p. 1612). The pseudogalls could also be provoked by growing young coffee plants in water cultures and increasing the salt concentration (s'Jacob, 1936a, p. 1651).

An extensive review of the coffee nematode problem in Java was published by Bally & Reydon (1931, p. 23), with full particulars on the history of the pest, the methods for studying it, the systematics of nematodes, the relations of the parasite and the host plant, and means of fighting the pest. The pathological anatomy of the attacked roots was studied by Pfältzer (1935a, p. 55).

In the course of years in Java, Tylenchus spp. must have destroyed large areas of coffee; and the genus must claim a large part of the crop in even more extensive areas as a result of its constant attacks. Zimmermann (1900-1901, p. 201) found them as deep as a half a meter. In his pioneer work in studying Tylenchus in Java (Nematoden, I, 1898, and Nematoden, II, 1900) he proved its severity. Tylenchus were found (Bally & Reydon, 1931) in old fields, which, notwithstanding their presence, produced good plantings with high yields. Wurth (1922, p. 29) who warned constantly against underestimating the danger of nematodes, recommended planting other crops in such fields or not replanting with coffee for several years.

It cannot be denied that on many estates in the Malang province, nematodes occurred generally without being disastrous in old plantings and that replanting in such fields was useless. On the other hand, a large part of these plantings were made on the ruins of old C. arabica plantings, and that although nematodes were found on C. robusta soon after its introduction into Java (Cramer, 1906, p. 191), it remained fairly resistant in places where C. arabica had been killed by nematodes (Bally & Reydon, 1931, p. 35).

Zimmermann (Nematoden, 1898, p. 36) experimented with artificial infection with T. coffeae on pot plants of C. arabica and C. liberica and found the former was attacked much more quickly and that the intensity of the infection was much less in the case of C. liberica. Replanting with it was generally successful in the field. Seedlings of C. liberica raised in pots with infected C. arabica remained free from the pest, even after having been transplanted to the diseased field. Cramer (Verslag, 1908b, p. 12) stated that he found T. coffeae only in C. arabica roots. He succeeded in infecting pot plants of C. robusta and C. uganda coffee with this species and warned against this danger to the newly introduced C. robusta. Anguillulina similis was found by Cramer in C. arabica, C. liberica, and C. robusta and also in C. liberica grafted with hybrids. Wurth (1908a) reported that samples of C. robusta roots with nematodes were received from many estates, but he did not indicate the species of the nematodes. A. similis was found to attack all kinds of coffee and even tea (Zimmermann, 1900, p. 8). In the beginning it was thought that the solution of the difficulty could be found by grafting C. arabica on C. liberica, since this kind was not so easily attacked. This apparently originated with a planter, van Riemsdijk (Ottolander, 1936, p. 360).

The first such grafts were made in 1888 (Kramers, 1900, p. 40) or 1887 (Ottolander, 1936, p. 360). Other estates also adopted grafting, but they met with little success, and the method was nearly forgotten. Grafting was again started in 1896/97 when the nematode attacks became serious, for they were much more widespread than originally assumed (Kramers, 1899, p. 539). Whole fields had died out and been replanted with C. liberica, and although this species was not immune, replantings often succeeded. Van Riemsdijk's grafting method again attracted the attention of many planters, and the grafting of C. arabica on C. liberica finally was adopted in many quarters. Even specially

trained nurserymen were engaged from Holland to supervise the work, and improve the technique. Kramers (1899, p. 564) described the enthusiasm of the planters in 1898, but the next year the attitude had changed as a result of fallacies in the new technique. New and promising methods of grafting had been devised, but C. arabica, especially the variety Maragogipe, were difficult to unite with C. liberica. Grafts which were successful while young often died later.

Zimmermann (1900, p. 20) unsuccessfully tried to find another Rubiaceae plant for a root stock. In later years the question of good stocks for grafting was studied by Cramer (1928, p. 5) not so much from the standpoint of resistance to nematodes as from that of general suitability. Seedlings of Robusta Bgn. 124.01, in reality a hybrid, "Robusta x Quillou", proved to be an excellent stock. This strain is still popular among planters for this purpose. Later it also proved fairly resistant to nematodes but it was not immune. In a test on the Karang-Anjer-Nongko estate, with seedlings and grafts of various estate mother trees and Robusta Bgn. 124.01, on old nursery land infested with the nematode, A. similis, the grafts on the seedlings of the latter and the ungrafted seedlings themselves showed a much more vigorous growth. They were not free from nematodes, but suffered less. The grafts on these seedlings also had fewer branch beetles (Henfling, 1933, p. 1363). This experiment was a typical instance of how a vigorous stock may help the grafts survive the nematode attacks.

It may be that selection of young plants for resistance before grafting may help to obtain good stocks. Reydon (1935, p. 39) found that generally 5 to 10 per cent of young coffee plants showed certain resistance to both noxious species of nematodes. This became visible as early as 3 to 4 months after infection. A nursery of Robusta Bgn. 124.01 on soil where there had been an old planting was found to contain many infected plants. Some of them remained healthy, even after 2 years. They were grafted, and these grafts then formed a close planting which gave a fair yield (de Fluiter, 1937, p. 1227). When several seedlings per hole from a strain known to be resistant were planted on infested soil and all apparently diseased infected plants removed after a year or so, those that were retained continued to be healthy and gave a fair yield in the first cropping year. These results opened promising perspectives for further increasing resistance by direct individual selection.

It is believed that the choice of a vigorous clone for grafting will have the same effect, since the vigor of the clones has a dominant influence. As s'Jacob & Hille Ris Lambers (1938, p. 44) formulated the situation, a vigorous clone, even if grafted on a weak stock, produced a vigorous graft. The vigor of the clone did not appear in broad growth, but rather in a better system of primary branches and their rapid reproduction. This habit probably explained the good stand of comparatively slender, but very harmoniously growing "Congusta" clones in nematode resistance tests (Vraagbaak, 1941, p. 121).

Nematodes were found especially dangerous to young coffee plants. Apparently Robusta Bgn. 124.01 showed a satisfactory capacity for root regeneration under certain conditions (Reydon, 1933a, p. 9). In recent years more attention was given to the scion clones and such vigorous ones as SA.56, SA.109, Bgn.83.03, Quillou 121. and BP.42, may develop into satisfactory grafts even on moderately growing stocks (Pfältzer, 1937a, p. 1367). When the nematode-resistance of various combinations was compared experimentally, the different stocks did not differ in resistance, but there were differences between the various clones. Congusta was the best in several cases.

Experiments in stimulating growth by manures have proved that coffee planted on a nematode-infested soil could be nursed more readily through the difficult early state by manuring, especially with nitrogen (Bally, 1932, p. 55). It was an experience that improvement of the soil by mulching was also effective in this respect.

It is preferable to submit the land before a replanting with grafted plants to a "starving out" process by keeping the soil free from coffee and from weeds, on which the nematodes can live, for a couple of years. A list of plants which could be infected with nematodes was published by de Fluiter and Mulholland (1941). Food crops like Ipomoea, batatas, cassava, rice, corn, and beans, are among the hostplants. One immune plant that may be used for covering the open places is Eupatorium pallescens, and most species of Crotalaria do not act as host plants.

BERRY BORER OR BESSENDOEROK

Berry borer is among the most noxious of the insect pests. It was first noticed on an estate in west Java in 1909. Van der Weale (1910, p. 1), found it on the coffee estate of Lampegan, west Java, where it attacked berries of Liberica coffee. It was so frequent there that berries free from the pest were rare. Little was heard of the berry borer, Stephanoderes hampei Ferr., on the Pamanoekan- on Tjiasemalanden in 1916 (Reepke, 1919, p. 5). After a while it decreased in intensity of attack, but in 1919 the berry borer was found in the Cultuurtwain, and in the beginning of 1919 the whole of west Java was found to be infested. By 1919 there was a decrease in intensity of attack.

In the beginning these variations in the frequency of the pest made some planters think that it would simply disappear. When nothing was done to combat it, Bally (1922, p. 43) published an earnest warning against giving up measures for its control and the further course of events showed that this warning was not out of order. At the end of 1918 the government station at Bangelan in east Java was reported infested, and the pest was also found on a few neighboring estates, although the other estates in the district were still free. In later years the pest spread all over Indonesia. In 1920 it was present on many estates in the Malang district (van Hall, 1921, p. 27). Arens (1921, p. 286) gave an idea of how the pest gradually spread in the Kediri province in east Java, and its spread on the east coast of Sumatra and Atchin was described by Corporaal (1921, with map).

It was one of the most serious threats to the crop, but it has been checked by countermeasures worked out by many able entomologists in Java. In view of the very serious character of the pest, a special fund, the "Koffiebessenboeboekfonds", was set up in 1921 to finance research on countermeasures (Wurth, 1922a, p. 1). Although the pest does a certain amount of harm and has greatly reduced the natives' coffee production the estate industry has learned to keep it under control. Still the borer requires constant watching and well-organized, somewhat costly countermeasures.

Stephanoderes hampei is a little beetle. The life history and other particulars are found in a study by Leefmans (1923) in Indonesia. The female is very dark, nearly black, with legs of a lighter shade. The female is 1.7 mm. long, the male 1.2 mm. The females emerge and fly, from 4 to 6 P.M. and when they get to a fruit, bore as quickly as possible into the coffee berry, preferably a ripe one. They only lay their eggs in beans which have already developed a hard endosperm. Larvae cannot develop in younger beans with fruit smaller than the size of a pea. Beetles may bore into very young fruit to feed. The damaged berries are generally dropped. The females can lay eggs for two months, and they remain in the bean once they have entered it (Vraagbaak, 1941, p. 307).

Control was aimed at reducing the number of beetles ready for multiplication. If only very few berries with hard beans were left on the trees, the competition from mature beetles was such that they destroyed the food for their offspring by feeding themselves (Friederichs, 1924, p. 261). In one experiment (loc. cit., p. 280) it was found that some females lived an average of 67 days as adult insects and laid an average of 37 eggs per beetle. The length of time for the development from egg to adult insect was determined by Leefmans (1923, p. 12) as an average of 25 days for the low altitude at Buitensorg. At higher altitudes it took more time (Friederichs, 1924, p. 269). This explains the very rapid multiplication if suitable berries are available.

The method of control was based on these findings (see Vraagbaak, 1941, p. 309). During the harvest, berries just turning pink or red, from the early stage of ripening on, were picked as completely as possible. By shortening the intervals between picking rounds the opportunity of multiplication of beetles was much reduced. The fallen berries were carefully collected, for otherwise they would be a source of infection. To allow thorough collecting of the dropped berries in plantations with green manures, it was better to use bushy green manurers (Friederichs, 1925, p. 112, note) as it allowed cleaner harvesting. The "lowewak Koffie" (excrement of the animal Paradoxururus hermaphroditus, consisting mainly of coffee beans) had to be carefully collected (Gandrup, 1922, p. 53).

When the climatic conditions on an estate are such that the crop comes in during part of the year, alternating with a period when there are no ripe berries on the trees, all berries, even the unripe ones, should be carefully collected (so-called "ratjostan") at the end of the harvest. The collecting of fallen berries is repeated. As soon as the crop begins to ripen, often a few months before the trees bear enough berries to make the harvesting pay, all berries which show the first signs of ripening are collected. When the commercial harvesting starts, a thorough removal of early ripening berries must again take place. It is clear that by such measures, thoroughly applied, there was a period in which no berries was available for beetle multiplication, and thus the life cycle of the pest was broken. The main point was to follow the method meticulously. If there was no delays in the picking, and if all ripe berries were brought in at short intervals, the pest could be kept under control (Gandrup, 1938, p. 12).

Factory cleanliness was also recommended. All beetle-infested berries were treated at once with steam in order to kill the beetles, for otherwise they would fly out and infect neighboring fields. For this treatment a steam ladder was designed (Hoedt, 1924, p. 248) by which the berries were exposed to the action of steam to kill the insects. Simpler devices were also used.

On estates with continuous crops, harvested all the year round, these measures could not be easily applied. There the fields were searched regularly for infested berries, even green ones. The difficulties in southern Sumatra in organizing an efficient campaign against the berry borer was difficult according to Hoedt (1928), because bearing was continuous. A thorough collecting of the dropped berries was practically impossible.

The pest is carried by seeds, but they can be disinfested by turpentine vapors without losing

their germinative power. This method was worked out by Begemann (1926, p. 208 and 1930, p. 45). His method found general application. It was confirmed by Haas & Boedijn (1927, p. 233). It is not possible to free the seed from the pest by even very careful sorting. When such seed was stored, one per cent was found infested a month later. After two months 11.5 per cent and after three months 26.5 per cent (Ultee, 1933b, p. 75). Another method for disinfection was studied by Mallamaire (1935, p. 70). He applied 50 g. of picric acid per cubic meter of seed for one hour. As Ultee (1936, p. 59) remarked in connection with this method, the gain in time was not so important in Java, where disinfection was especially necessary, and the action of the chemical on the stored seed had not yet been studied.

A general policy in combatting the pest should be based on a good understanding of the principles already noted. It is clear that it is a bad policy to mix trees with different ripening seasons in the the same planting. They should be planted in separate blocks, and countermeasures should be organized individually for each block, with careful supervision of continuous boundaries.

A control method invented around 1922 by a planter named Develaar involved smearing berries with a mixture of axle grease and kerosene, and was somewhat successful (Hallauer, 1923) but very expensive in labor. It was modified in the "touch" method ("aanstip-methode") by which only the attacked berries were touched with a mixture of six parts of axle grease and one part of kerosene (van Hall and Rutgers, 1922, p. 81). Friederichs (1923, p. 152) considered this method valuable as a complement to the method prescribing thorough removal of the last berries of the crop and the dropped berries.

The boeboek beetle has several enemies. The "boeboek fungus" was discovered by van der Weele and studied by Leefmans (1923, p. 51). It forms a powder on the small holes of the insect's entrance. An extensive study of the parasitic fungi, the most widespread of which is *Botrytis stephanoderis* Bally, was made by Friederichs and Bally in 1923. An Ichneumonid, *Prorops nasuta* Was., was introduced in 1924 from Uganda, where it was known to attack the boeboek. Thousands of these parasites were freed in Java, but did not seem to become established in Indonesia (Vraagbaak, 1941, p. 311). *Dindymus rubiginosus* F., which pulls the beetle out of the berries and sucks it dry, was found and described by Wurth (1922c, p. 51). None of these enemies kept it under control.

The altitude appeared to be a limiting factor. In Uganda the ecological limit is above 1,600-1,700 m. In Java, Friederichs did not find boeboek at this altitude, but at 1,100 it was found in quantity, although the life cycle was longer (Friederichs, 1924, p. 268).

Leefmans (1923) gave attention to the susceptibility of the various kinds of coffee to the pest. Low percentages of attacked berries were found in *C. dybowskii*, 6.5 and in *C. stenophylla*, 9. The figures were only slightly higher for *C. abeokutae*, 16, and for *C. excelsa*, it was 17. For *C. robusta* it was 34 per cent, *C. quillou* 73, and *C. ugandae* 65. *C. perrieri* showed only one attacked berry (table 15, p. 86). Friederichs (1924a, p. 315), citing Leefmans, stated that in the Cultuurtuin the percentage of berries with larvae was 2.3 for *C. dybowskii*, 3.5 for *C. liberica*, 3.8 for *C. abeokutae*, 4.7 for *C. excelsa*, 6.9 for hybrid *Liberica x Arabica*, 23.4 for *C. robusta*, and 58.7 for *C. quillou*. Such figures have only a relative value, since the presence of one species with a high percentage of affected berries may influence the percentage in another species planted next to it. In a count made in various species at the old selection station at Boger Redjo, in south Sumatra, somewhat similar figures were found. *C. stenophylla* was also included and showed a low percentage of attacked berries as well as low percentages of beans with larvae (Friederichs, loc. cit., table and note on p. 354).

It was further found that in libericoid species the difference between attacked beans is much larger than in robustoid types, a fact that can be explained by the harder parchment skin. Huitema reported 13.2 per cent of affected *C. excelsa* berries in Taponeeli in 1929, 74 per cent in *C. robusta* and 76.8 per cent in *C. quillou*. *C. dybowskii* was among the least susceptible kinds. At Boger all the berries and beans of *C. congensis* were infested. The Kawisari hybrid was more susceptible than the libericoid species. *C. arabica* always appeared very attractive to the berry borer, but it was generally grown at altitudes where the pest was less common. Among the robustoid species, the boeboek liked *C. quillou* particularly. *C. uganda* and *C. canephora* also seemed very attractive (Friederichs, loc. cit., p. 330-331).

Susceptibility may vary not only between different species, but also between different clones. In tests on various estates in the Malang region Sneepp found that SA 13 and 34 were least attractive clones to the pest. In the Cultuurtuin it was found that the percentage of boeboek infection in the beans of the QF hybrid was low, much lower than for robustoid kinds. As an absolutely immune species *C. schumanniana* can be cited (Schweizer, 1925a, p. 312). According to Leefmans, instances were found by Wurth in which it had been attacked, but it is not known whether the berry borer can multiply itself in the berries.

At Kalivining the Besuki Institute compared some libericoid species but found no reliable dif-

ferences in susceptibility between them. Of 99 C. dybowskii trees 16 were free from attack the year round. Among them were 3 of the highest producers, and the crop ripened in 4 months on all 16 (loc. cit., p. 306). It was also found in the case of the other trees that the shorter the harvesting season, the lower the percentage of infestation. In some cases it appeared that 3 liberoids, C. excelsa, C. abeokuta, and Kawisari Hybrid, were less susceptible than Robusta in regions where there was no pronounced dry season.

It is difficult to estimate losses caused by berry borer, since it attacks at different stages of the crop. It causes unripe berries to fall, and this loss cannot be calculated. The harm to the harvested crop includes production of a large proportion of second grade product because of the infested beans. For instance, in C. robusta it was 47.8 per cent second grade from borer infested crop compared with 3.6 in non-infested. In hybrids (Liberica x Arabica) it was 54.9 against 23.6. and in C. excelsa it was 41.6 against 4.5 (Friedericks, 1924a, p. 322, and table III, p. 323). Studies were also conducted on losses in weight from infestation and on one estate the average loss was found to be 21 per cent with an infection percentage of 43 of ripe berries. Another estate with an infection of 19.2 suffered a loss of 2.2 per cent (Betrem, 1935, p. 1226). De Lig (1931, p. 176) found a loss of 7.7 per cent with an average infection of 20. In southern Sumatra the continuous cropping period leads to much heavier losses (Keuchenius, 1936a, p. 448). In one instance 22 per cent of market coffee was lost with a proportionally low infection percentage. On Soember Asin the loss was 2 per cent with a 4.5 per cent infection (Betrem, loc. cit.). These figures, all for estates where measures were taken against berry borer, showed that the percentage of infested berries did not allow proper estimate of the loss. A review of berry borer infestation of the crop in Besuki gave figures varying between 13 and 18 per cent for the period 1930-1934. Many of the estates were opened under unfavorable conditions, but some succeeded in reducing infestation to less than 10 per cent by a thorough application of the measures used against the pest (van der Veen, 1935, p. 457).

After Stephanoderes had been unmasked as a very noxious pest in Java, a similar insect was found in coffee berries in Surinam and was first thought to be the same as S. hampei. However, on closer examination it was found that the beetle was present only in dried berries, never in juicy ones. It was determined as a different species, S. plumeriae or possibly a new species, S. subopacus. From these studies it apparently did not cause any harm to the coffee crop, since the black and dried berries were not used for making a market product in Surinam (Verslag Suriname, 1924-1927, p. 9).

BRANCH BORERS

There are two other beetles in Indonesia resembling the berry borer, which damage the coffee tree, both of which bore into the branches. These are the brown and the black branch borer.

In about 1930 the branch borers were considered a pest which threatened the very existence of the Robusta planting industry. It also attacked Tephrosia and Crotalaria used for green manure. "The subject was often discussed in planters' conferences and in the Bergcultures in 1931". A pessimistic view of the situation was taken by some of the planters who visualized the possibility of the complete ruin of Robusta plantings (Stadt, 1931, p. 1073).

The brown branch borer, Xylosandrus morigerus Blan, was not yet known as a coffee pest when it was first discovered on Robusta in November 1906 and described by Wurth (1908a, p. 55), who considered it a serious pest. Its habits are similar to those of the more dangerous pest, the black branch borer, Xylosandrus morstatti = Xyleborus morstatti. This pest has become common in Indonesia only in recent decades. The beetle is jet black, 1.8 mm. long and plump. The female gnaws through the bark and wood of branches ranging in age from 6 to 24 months and creates a cavity in the center (Vraagbaak, 1941, p. 301). On the walls of this cavity an ambrosia fungus develops on which the beetles and the larvae feed. The females emerge between 4 and 6 P.M. Their life is short when they are unable to penetrate a branch. The males are much smaller and wingless. A female makes only one cavity with larvae. With the ambrosia fungus there is a development of certain other secondary fungi such as Diplodia, which may cause the branch to die. The insect can only live upon the ambrosia fungus, and thus if the condition of the branch does not allow its development, the beetle cannot exist. This is the case in the dry season and also the case with vigorously growing branches. The pest thrives on weak branches and on trees which are in a poor condition. The strength of the tree is of special importance and should be improved as much as possible by increasing the water capacity of the soil and by providing a good but not too heavy shade (Betrem, 1934, p. 73; s'Jacob, 1934, p. 1049). Begemann (1928-29, p. 21) described the application of the statistical method in an investigation of the branch borer.

When a dead branch with a hole of a branch borer is found, it is not certain that the pest caused the dieback. Betrem (1932, p. 57) believed that this dieback depended on various external

conditions which were only indirectly associated with the pest. Coffee trees often lost a certain percentage of branches, especially when the water capacity of the soil was unsatisfactory. When Robusta trees were attacked their branches died seriously. As long as the tree could defend itself by natural means it was not possible to reduce the loss of branches by direct measures against the branch borer (Betrem, 1934, p. 82). Therefore, it was felt that direct measures against the pest were useless. The remedy was to put the tree in a better condition and to avoid sudden changes as excessively heavy pruning of the shade.

Betrem (1931, p. 799) found that in a young planting the painting of the underside of the branches with a grease might be beneficial. Shortly after the publication of this statement a planter (Gerretsen, 1931, p. 1080) gave a description of the manner in which this procedure had been applied. Good results were obtained with Gargoyle Mobil grease no. 2 (Mondt, 1934, p. 606). In a later report the loss of smeared primary branches was reported as only 8 per cent, while with trees on which this method was not applied the loss was 40 per cent before the fruiting started (Mondt, 1935, p. 430).

Some figures obtained for Robusta trees planted at Bangelan toward the end of 1931 indicated that with grafts the clones as well as the stock had an influence on the loss of branches. Quillou Bgn. 121 lost less branches on all stocks than Robusta Bgn. 83. These clones lost the largest number of branches on seedlings of Ugandae Bgn. 2a stock. With the same families of ungrafted seedlings the order of merit with respect to the loss of branches was different. Therefore the suitability of a family for stocks from the standpoint of loss of branches could not be judged from the figure on the loss of seedlings (Betrem, 1935a, p. 432). There were clones which suffered less from the branch borer than others. Ferwerda reported (1935a, p. 433) that Bgn. 201.01, 325, 83.03, and Quillou 121 were among this group.

The brown branch borer appeared for the first time in 1906 on the Kawi mountain. In the second half of 1927 the black branch borer was observed there for the first time (Ultee, 1931c, p. 1099-1100). The brown branch borer *Xylosandrus morigerus* Blauf. resembles the black borer except that it is brown. It has been crowded out by the black borer. It lives in the main root and branches of many plants. Like the black borer it is a pest of secondary character and can best be fought by improving the general condition of the attacked trees. It was first described by Wurth as early as 1908e (p. 63). He also found the beetle on shade trees: dadap, *Erythrina*, and mindi, *Melia asedarach*, but not on two of the coffees, *C. arabica* or *C. liberica*. Wurth thought it not improbable that these species were also attacked, even though only very sporadically. The best host plant appeared to be Robusta coffee trees two or more years of age.

SCALE INSECTS

There are many scale insects living on the leaves and berries of coffee, and sometimes they can do considerable damage, especially in young plantings during the dry season. The most important ones as observed in Indonesia have been the green scale, *Coccus viridis* = *Lecanium viride*, and the brown scale, *C. hemisphaericus* = *L. hemisphaericum*. According to work by Koningsberger in 1896 the green scale, which he found all over Java and present on virtually every coffee estate, was probably introduced with Liberian coffee. Koningsberger & Zimmermann (1901) referred to the green scale as "without doubt one of the most dangerous enemies of the coffee planting industry". That this was the general conviction in those days is clear from the fact that in 1899 the General Coffee Syndicate, the coffee procedures association, offered a prize of 2,500 Guilders including a contribution from the government of 1,000 Guilders for the most practical and efficient means for destroying the pest (advertisement in "Koffiegids", 1899-1900).

Soon after the introduction of Robusta into Java it was found to be susceptible to the green scale. In a field with 8 different kinds of coffee it was the most severely attacked (Wurth, 1908a, p. 55). The pest can only be dangerous when it is helped by ants, and in the middle belt it is generally the "gramang-ant", *Plagiolenis longipes*, which lives on the "honey dew" of the scales. Van der Goot (1916) noted that the number of scales in a colony which ants could not reach remained stationary for 5 months, while in another colony visited during the same period by gramangs, it had increased to 20 times the original number (Begemann, 1928, p. 425). The mortality was considerably less, the development of the scales more rapid and abundant, and they were less subject to parasites. In British India a similar influence of ants on the development of scales on coffee was observed (Coleman & Kannan, 1918).

The only efficient way of keeping the pest under control in Indonesia, in places where it did serious damage to coffee, was by fighting the ants. This was done by one of two methods, viz., the boemboeng method and the catching hole method. The first one, discovered by planters through experience (van der Goot, 1915, p. 52), consisted in laying a bamboo tube (Boemboeng) closed at one end in the shade under a coffee tree. A couple of coffee leaves were put in the open end and all sorts of other material the ants used for making their nests in the vicinity such as dry leaves, mulch,

dead wood, etc., were buried. The ants were found to transport their nests to the boemboeng, which were inspected at the beginning of every other day. If they harbored ants, these were emptied into a tin with boiling water or in water covered with a thin layer of solar oil. The latter was not allowed to touch the boemboengs, since the odor would keep ants away from boemboengs when they were put back in the field. When more than half of the boemboengs were found to be empty on a single inspection round, the intervals between inspections were lengthened.

Preparatory measures in the case of the catching hole method are similar. The ants were lured into holes of about $2\frac{1}{2}$ x $2\frac{1}{2}$ feet, on the bottom of which was a thick layer of leaves. If the holes contained ants, the insects were killed by putting a spoonful of calcium cyanid under the leaves. The boemboeng method was more suitable for the rainy season, the catching hole method better for the dry season. The first method was generally cheaper and more successful, but the measurers had to be continued for months before results were apparent (Vraagbaak, 1941, p. 345). The successful application of calcium cyanid to the gramang ant for eliminating the green scale was described in 1932 by Trautmann (p. 379) and Snoop (p. 545). Both also gave figures on the costs. In a short note on green scale Keuchenius (1914a, p. 41) mentioned that the "ngrangang" ant *Oecophylla smaragdina* kept the scales in their nests and protected them from outside enemies (Keuchenius, 1914a, p. 23). In a later study more data were published on this point. An ant poison recommended by a planter in 1936 for fighting ants (van Prehn, 1936, p. 907) did not seem to have been applied on a large scale.

The damage done by green scale to coffee was estimated by planters at a high figure. In one case, for instance, a third of the crop, in another at 4.5 q./ha. (Keuchenius, 1914, p. 17). No further data are available on the extent of damage, but it is so considerable that Begemann called the pest one of the most serious ones, for both *C. arabica* and *C. robusta*. It had been somewhat overlooked as a result of the attention given to the berry borer, but much dropping of young fruit, often attributed to the berry borer, was the work of the green scale. It was often thought that scales lived only on young leaves and branch tops, and their presence in fruit whorls was overlooked. When young plants were attacked, their growth was retarded considerably.

DOMPOLAN MEALY BUG

The dompolan mealy bug, *Pseudococcus citri*, was found commonly in the whorls of flowers ("dompolans") of various coffee species, on *Leucaena* shade trees at altitudes above 600 m., and on various green manurers. It became a real pest when its reproduction was accelerated. The main factor for its increase was a low moisture content of the air, under 70 per cent, since its main enemy the fungus *Empusa regenii* Nowak, cannot develop well under such conditions. The state of the shade also had some influence. When there was little shade, the coffee became a good source of food for lice. Gramang ants could increase the pest. The actual damage done by the dompolan scale was difficult to estimate, since in years when the pest was very frequent, the drought alone also did a great deal of harm to the plantings. The insect was especially harmful in the young fruit whorls (Betrem, 1932a, p. 559). Two beetles of the lady-bird genus, *Scymnus*, live upon the lice.

Fighting the pest is difficult. Betrem (1933, p. 84) found that coffee trees could be treated with hydrocyanic acid gas without damaging the white scale, while the green scale was 90 per cent exterminated. Experiments in the application of cyanogas to kill the branch borer were not successful. Large scale application probably would be too expensive. Measures against the pest consisted mainly in an intensive fighting of the gramang ant (supra), avoiding the planting of susceptible green manurers, such as *Calopogonium mucunoides*, *Desmodium gyroides*, and varieties of *Tephrosia*, and not permitting shade to become too light, using a mixture of lamtoro, dadap, and sengon. Experiments on the influence of shade on the development of the pest showed a heavier attack for the plots under lamtoro alone than for the plots where the shade had been made denser by planting lamtoro and dadap (de Fluiter, 1936a, p. 847). In places where lamtoro, or *Leucaena* shade, and coffee, show insufficient growth — and it is here that the pest appears first — shade trees other than lamtoro should be planted.

Direct measurers such as painting the insects in the dompolans with soap emulsion of solar oil in the beginning of the dry season, were found too expensive when applied on a large scale. However they were used for suppressing the centers of infection in the beginning. A good description of a case in which careful practical countermeasures were carried out by tracing and destroying the heart of the infection was given by Reydon (1933b, p. 977). On estates above 600 m. the mealy bug attacked lamtoro before the coffee. The measures against it consisted in preventing the flowering of the shade trees as much as possible, cutting back alternate rows in alternate years, and taking all small twigs from the remaining rows.

The success depended on the vigor of the lamtoro and on establishing a second shade roof of *Albizzia* above the lamtoro, a situation which counteracted the development of the pest on the lamtoro. An excellent measure was found to be the planting of non-flowering or less-flowering forms

of it. As such, grafts of seedless strains of Leucaena glauca, of L. pulverulenta, or of the sterile hybrid of glauca x glabrata were used. A distinction must be made between the white of the lamtoro, Ferrisia virgata, and the dompolan, Pseudococcus citri. On estates in higher altitudes both pests are fought by the same measures. Since the lamtoro-scale lives not only in the flower heads but also on leaves, twigs, and branches of lamtoro, it seemed to require a more drastic pruning than the dompolan scale on the lamtoro (de Fluiter, 1937a, p. 955). The occurrence of coffee trees that were more resistant to dompolan scale, was mentioned by de Fluiter (1936, p. 1639). He found located in an extension which suffered badly from white scale, a field with grafts of a special clone that was only slightly attacked. He also described results of fighting Pseudococcus citri on the higher estates by pruning the centers of infection as soon as the pest attacked lamtoro.

On several estates the coffee could be kept free from scale by pruning. One disadvantage was that the coffee was exposed suddenly to the sun in the dry season, but this risk had to be run. The effect of the sudden exposure was that the coffee formed numerous small shoots which might take away reserve food from the flowering and reduced next year's crop. When another shade tree such as Albizzia, Acacia decurrens, or dadap was present with the lamtoro, these extra shoots did not develop. In the lower belt, at an elevation under 700 m., the white scale occurred primarily on the coffee. Here the centers of infection were treated with oil-soap emulsion successfully.

With a total yield of 20 q./ha. the emulsion treated fields gave 3 q. more than the untreated ones, but this was too expensive for practical use. In other fields the shade was made heavier; and while the scale became less frequent, the excessively heavy shade also reduced the coffee crop. In fields where the dried flowers had been taken away, much fruit was saved. The clone developed from a resistant mother tree also withstood the pest in 1937. De Fluiter returned to the shade problem in 1939a (p. 766) and advised against too much shade. The establishment of a 2 or 3 storied shade roofing, of dadap, Albizzia, and lamtoro, allowed heavy pruning of the latter, if necessary, in view of the dompolan scale.

A serious attack of the dompolan scale can result in the loss of the whole crop in the attacked fields. Betrem (1936b, p. 166) cited a case in which such a field yielded no crop at all in 1934, while other neighboring fields that were free from the pest yielded 7 to 8 q./ha. After the rainy season of 1935, the attacked fields had recovered fully and showed no further ill effects. In a series of articles by Betrem in the Koffie Archief, volume 10, 1936, a full account appeared of the biology, and control of the white scale. In the same periodical he gave in 1937 an account of the morphology and systematics of some mealy bugs of Java. This series was completed by de Fluiter (1941, p. 1), who gave special attention to the occurrence of the pest on the estates in higher altitudes such as the arabian coffee estates on the Idjen plain. Conditions are entirely different there from those of the Robusta estates in the lower belt. For instance, on the latter the scales can be kept under control by making the shade heavier, while on the Idjen estates the attack was heaviest in the fields with the densest shade.

CERETS OR WHITE GRUB

The larvae of Scarabaeidae may do considerable harm, especially to nurseries and young plantings. The adult beetle feeds on leaves. They generally lay their eggs in the soil in the beginning of the rainy season. The complete life cycle in Indonesia takes about a year. Some species live on dead leaves under a cover crop, in compost heaps, etc., and if there is not enough available feed they may do damage to living roots.

Another group, which is not able to crawl, but moves otherwise, includes the noxious species, Lachnopterna serverini and Holotrichia leucophthalma. Measures to protect the coffee plants against their attacks consist in permitting harmless weeds to grow between the trees so as to prevent concentration of the insects on the coffee trees, general improvement of the growth of the trees so as to increase their root-forming power, and supplying with old stumps. A case of an estate is recorded on which supplying was done with 12,000 young plants and 1,700 old stumps seven to ten years old. Of the young plants only 10 per cent survived, and of the stumps only 180 did not succeed (de Fluiter, 1936c, p. 424). Fighting the pest directly with chemicals was found too expensive.

GANGSIR, THE INDIAN CRICKET

The Indian Cricket, Brachytrupes protentosus Licht., lives in a hole from which it emerges at night for food. It may bite off young coffee leaves in nurseries and leaves from young plants which have just been set out. In nurseries they can be traced and killed. When the bods can be put under water, it is easy to find them, since when flooded they come to the top. Where the insects are frequent young plants can be efficiently protected by putting a piece of bamboo, 10 to 15 cm. high, around the stem, since the insect cannot pass over it. On an estate where the pest did a good deal of damage an experiment was conducted with the poisoning of the insects in the holes with calcium

cyanid, but it was found that digging the insects was cheaper (Gandrup, 1934a, p. 580).

OELER KAWAT

In nurseries the "oeler kawat", a species of *Opatrum*, sometimes does damage. The larvae eat roots of young coffee plants. If they are found in nurseries in large numbers, it was found best to transplant the young plants to another tract that is free of the pest.

The pests mentioned thus far have long been known as enemies of coffee, and they were all described in the older publications by Koningsberger (1897) and by Koningsberger & Zimmermann (1901).

XYLOTRECHUS

Another pest, the white coffee borer *Xylotrechus javanicus* Lap. et Gory, also once was serious, but it seems no longer to be a danger. It was found in the stems of *C. arabica* young or old, in several districts of Java, and the attacked trees generally died. When it was first discovered it was not doing much harm. As Koningsberger put it (1902-1903, p. 538), it was "an animal which has only one of its six legs in the domain of the estate fauna, the other five still in that of the jungle fauna". At that time it was threatening, but a case was mentioned in which it did considerable damage.

Xylotrechus quadrupes is a borer which is one of the most serious enemies of Arabian coffee in Tonkin and also in British India (Coleman, 1934, p. 310). That no more is generally heard of the *Xylotrechus* in Java may be attributed in part to the replacement of *C. arabica* by *C. robusta*.

WILT DISEASE OR PHLOEM NECROSIS

It is not the purpose of this book to survey all the diseases and pests attacking coffee in the various coffee producing countries, and attention has been limited to the principal ones of importance to the crop in Indonesia. Exception will be made in the case of one special disease found in South America, the phloem necrosis or wilt disease of Liberian coffee in Surinam, occurring also in neighboring British Guiana. The cause is a Trypanosomide, a species of *Phytomonas* (Verslag Suriname, 1928-1930, p. 30-31). The disease was first described in 1917 by Stahel, who stated that it had been the most serious disease on Liberica in Surinam for two decades. The loss may be heavy on some estates, but on most estates the annual loss of trees as the result of the action of this pest is less than one percent (Stahel, 1917, p. 1). Further investigations were made to find out how the pest was carried from one tree to another, and various insects were suspected as vectors (Verslag, 1931-1932, p. 24-27; Stahel, 1934, p. 3).

CHAPTER 10 GENERATIVE MULTIPLICATION

FLOWER FORMATION

The biology of the flowering and the setting of the fruit in coffee is important in connection with breeding and in the successful fertilization and development of the seed. The development of the flowers of various kinds of coffee, has been studied by van der Meulen (1939) under different climatic conditions. It was found that in a climate with a pronounced dry season as in Bangelan, the genesis of the flowers occurred in the second half of the wet monsoon and in the beginning of the dry monsoon. In a climate wet during most of ten years the formation of flowers was more continuous. Gradually fewer and fewer flowers originated, but the flower primordia were never entirely absent. From these primordia the flower bud developed. At first the lobes of the calyx became visible as small protuberances, then the petals, and the anthers originated within them. After that the axis in the center grew in length, and the two loculi were formed. The central axis became the placenta, and the carpellae grew out to the long style with stigma. The whole then stretched considerably in length; the calyx inclosed the gynoecium and became one with it; the petals united basally and with them the filaments of the anthers. On the gynoecium inside the petal-tube the discus was formed, and in each of the loculi an ovulum, filling the cavity of the loculus. At the same time the obturator originated, and it acted as a conductor for the pollen tube. The flower was then ready to open (de Haan, 1923, p. 35). The time needed by the flower for arriving at this stage after the last resting period, might differ one or two days so that, although individual flowers last only one day, the flowering of a coffee plant would last two or three days, with the later flowers from the later opening buds.

POLLINATION

Pollination might take place while the flower bud was still closed. In *C. arabica* self-pollination often took place in the closed flower bud, where the anthers are in close contact with the lobes of the stigma. Self pollination by hand in that species led to a fruit setting frequently as high as 80 per cent (Krug, 1935, p. 327). With *C. liberica* the anthers in the bud were found to touch the pistil and shed their pollen grains on the pistil (Zimmermann, 1904, p. 96). By the time flowers opened some of these grains had already formed their tubes. However, if shortly after the opening, pollen of another flower happened to fall on the same pistil, this developed a tube growing much quicker than those of the flower's own pollen. It appears that the tube from the foreign pollen grain reached the micropyle first and penetrated into the ovule so that fertilization was most surely carried out by the foreign pollen (von Faber, 1912, p. 107). After spontaneous autogenous pollination the fecundation took place after 5 or 6 days, with xenogamous pollination after 3 or 4 days. In studies in Indonesia with other liberoid species, the process was the same.

In studies of *C. robusta* and its allied species, except *C. quillou*, they were found to be different, since in these the styles of flowers on the same tree varied a good deal in length. In the flowers with long styles the anthers did not touch the pistil, and self fertilization was impossible. In the case of *C. quillou*, flowers were of different size and behaved like *Liberica*. Ferrerda (1936) noted that in the case of *C. robusta* and *C. liberica* and *C. arabica* hybrids, pollen grains were found in many pistils just after the opening of the flowers.

Hille Ris Lambers (1929, p. 24) was the first to direct attention to the necessity of cross pollination for *C. robusta*. In the annual report of the Malang Institute for 1927 he stated that *C. robusta* branches, isolated by mosquito nettings, showed a strikingly reduced fruit setting in contrast to *Arabica*, where it was abundant under those same conditions. He also found the same thing in cases of crosses of robustoid species with other robustoids. In the *C. arabica* and the Kawisari hybrid the fruit setting after cross-pollination was much better than after self-pollination. In the case of *C. arabica* there is practically no difference. In 1928 Hille Ris Lambers again drew attention to this characteristic of *Arabica* in contrast with *C. ugandae* and *C. laurentii*. The autofecundation made under cages of mosquito netting at Seember Agin in 1927 gave little or no seed. Crossings between various *C. robusta* mother trees succeeded very well under such cages (Hille Ris Lambers, 1929, p. 31). The eleventh meeting of the Association of Research Workers the Vereeniging van Proefstation Personeel, in 1930 discussed the replies to a questionnaire on the manner in which breeding was done. It was again Hille Ris Lambers (1929, p. 78) who mentioned the difficulty in getting a sufficient number of seeds after self-fertilization.

The reply from the Agronomic Service of s'Lands Caoutchoucbedrijf, then in charge of the Bangelan Station, expressed a slightly different opinion. Although forced autofecundation leads to poor fruit setting, the pollination of a large number of flowers, apparently gave a sufficient quantity of seed. It may be expected that the pollination of grafts of the same mother tree would

give a better fruitsetting than autofecundation directly applied to flowers of the mother tree. Hille Ris Lambers (1932, p. 16) described other cases of incompatibility when he made crosses of various *C. robusta* clones and compared the results with the fruit setting of flowers protected against cross-pollination. He was also the first to note that, in general, within a monoclonal block the setting of the fruit was lower as a consequence of the self-pollination occurring there. Shortly afterwards (1933a, p. 587) he emphasized the preference for cross-pollination with *C. robusta*. The pollens of some clones, like SA.158, when used to fertilize other clones, gave 60 to 80 per cent of success, while it was only 1 per cent when used on its own flowers.

Hille Ris Lambers (1934a) then made extensive experiments with spreading pollen over a monoclonal planting of Robusta by various means, for instance, with a Björklund duster. With this device the pollen collected from other plantings was suspended in the current of air blown out. At twenty meters from the duster the current could still be felt and pollen, let loose there, could still be seen floating in the air.

The observations made by Hille Ris Lambers have been followed by the studies of Ferwerda (1932, 1933), on the same subject. He found that large monoclonal fields generally showed a comparatively low yield, and therefore the mixing of several clones was recommended. An alternative was to mix clones with seedlings. This self-incompatibility was specially shown by *C. robusta*, a pronounced cross-pollinator, while *C. liberica* and *C. excelsa* were also known to prefer cross-pollination. After a number of "fertility-crossings" made for investigating the extent to which flowers of a clones would set fruit with their own pollen and with pollen from other clones, Ferwerda (1933) came to the conclusion that cross-pollination generally gave a better setting of fruit than self-pollination and that large variations occurred between the percentages of success with various combinations, and it was therefore safest to plant mixtures of 5 to 10 clones.

In the case of Arabica in Brasil, field observations led to the conclusion that approximately half of the pollinations were cross-pollinations (Mendes & Krug, 1938, p. 13). Stoffels (1936, p. 25) studied the pollination of *C. arabica* in the Kivu region of central Africa and found that autofecundation was the rule. Artificial self-pollination gave 77 per cent success. Autofecundation could take place before the opening of the flowers, but this was an exception.

Only *C. arabica* and Liberica-Arabica hybrids set fruit with their own pollen. In Indonesia, other hybrids of *C. robusta* with *C. excelsa* and or *C. congensis* with *C. ugandae* behaved more like *C. liberica* (Ferwerda, 1936, p. 33). Crosses were made to find the extent to which a combination of clones were mixed in planting, while the same clones were also planted in monoclonal fields. From yield investigations it was possible to determine cross fecundations in the mixed field.

For several Robusta clones the surplus from mixing ranged from 13 to 65 per cent with an average of 50. For the tested Congusta clones the average was 36. With Kawisari hybrids the effect was negligible, but with the QP. hybrid an increase of 22 per cent was obtained (Ferwerda, 1941, p. 557). For practical purposes, the results of this research indicated that it was generally not desirable to plant pure monoclonal blocks of these coffees, but to mix clones with other clones or with seedlings to avoid the bad effects of self-incompatibility. It had been suggested at one time that experiments should be started on pollination with pollinators which showed high chromosome count (Frahm-Leliveld, 1938a, p. 25).

In view of the necessity of abundant pollination for obtaining satisfactory fertilization and fruit setting, the quality of the pollen was also an important factor. Ferwerda (1937a, p. 135) also studied this point. He found that pollen of Robusta, Excelsa, and Congusta when fresh contained only occasional defective grains. The pollen of some interspecific hybrids between *C. liberica* and *C. arabica* and between *C. arabica* and *C. robusta* were far less germinative, and shriveled grains were common. The pollen of the QP. hybrid showed better germination than that of Kawisari and analogous hybrids. When kept without special precautions, the pollen of the first kinds germinated quite well when 2 to 3 days old and to some extent after a week, but did not germinate after 10 days. If kept above quick line from the first, pollen still germinated after a month to 6 weeks, but the germination was slower and the percentage lower (Ferwerda, 1937a, p. 147).

It was found that if the land was flat and open, where coffee was planted, pollen could be carried (Ferwerda, 1936, p. 40) by moderate wind over a distance of 100 meters and at a height of 8. However at a distance of more than 15 the quantity was considerably dissipated. In accordance with this last observation an isolation belt of 15 to 30 meters was judged sufficient.

The total quantity of pollen which, with large flowering, was floating in the air above and between the coffee trees, was estimated as sufficient for fertilizing all stigmas only under very favorable weather conditions. It was presumed that with smaller flowerings or with less favorable conditions the fecundation is insufficient (Snoep, 1940, p. 279).

Hille Ris Lamberta (1937, p. 791) experimented with increasing the possibilities of cross-fecundation by spreading pollen artificially over test plots of fields and then comparing the yields

with those of the rest of the field. The pollen was generally spread with "flit" guns. To study the effect, the number of berries per branch and the yield per tree were determined. He thought that in some cases it was definitely proved that artificial pollination increased the setting of the fruit and that in many other cases there were strong indications of such influence.

In 1937 Hille Ris Lambers also studied the question of bees as an aid to pollination between different trees. Earlier investigations in Holland had led to the conclusion that the importance of the common honey bee, Apis mellifica, for cross-pollination in branches had been exaggerated. The alleged transfer of pollen over rather great distance from one tree to another apparently did not take place (Minderhoud, 1931, p. 52). Franssen (1932, p. 1420) studied the action of Apis indica as a pollinator and came to the conclusion that its role could not be very important, since the bees generally visited only one tree and then returned to their nest. They could at most increase self-pollination or cross-pollination only slightly even when branches of two trees were intermingled. Hille Ris Lambers (1937, p. 791) reviewing these investigations and completing them with additional observations and deductions, concluded that theoretically A. indica could contribute to cross-pollination especially when coffee trees of one kind were wholly surrounded by others of an interfertile kind.

ROUND BEANS OR PEA BERRY

When one of the two embryonic beans enclosed in a single berry fails to develop in the early stage, the other one takes advantage of the supplementary space and becomes a round bean, the "pea berry" of commerce. If this failure occurs later and the parchment skin of the failing partner has already formed as a hard tissue, the normal bean cannot take this round form. The failure can have two causes: (1) the whole development of the embryo sac has failed before fertilizations, or (2) the fecundation failed to take place, often because of insufficient pollination. The latter has seemed to be the most frequent cause of "pea berry" with Robusta. The failure of the embryo sac to develop is most frequent with Congusta hybrids and also with their parents Ugandae and Congensis. Empty beans or "voosboon" are those which have a normal parchment skin containing only a remnant of a bean (Frahm-Leliveld, 1938b, p. 155). Cramer (1913, p. 33) distinguished between the beans in which the failure of the embryo occurred early and which developed into a small empty scale "schilferboon", having a round bean as a partner, and empty beans or "voosboon", in which the failure took place later and for which the parchment skin developed to normal size but contained only a shriveled remnant of the seed. The latter were generally found in large numbers in berries of hybrid coffee. These empty beans were considered as partly defective beans in which the embryo generally developed normally, but with a defective endosperm. The entirely defective bean was found in pure species, C. robusta, and C. excelsa, and also in hybrids, to which the partly defective seeds were restricted. Both kinds of imperfections could cause losses in yields up to 30 or 40 per cent. A good setting of fruits and self- and cross-compatibility were generally associated with a low percentage of defective seed (Ferwerda, 1937b, p. 119).

The failure of one bean to develop in the berry, with the consequent formation of round beans, leads to losses, since a round bean weighs about the same as a flat bean, while the "deal weight" of a berry is about the same for one round bean as for two flat beans. A high percentage of round beans is thus considered undesirable. The trade also objects to it. There has been complaint that Congusta hybrids contained too high a percentage of round beans. As early as 1910 von Faber (1910, p. 573) stated that the cause of empty beans might be the abortion of the embryo sac or the deficient growth of the pollen tube from the flower's own pollen. Frahm-Leliveld studied this situation (1940a, p. 1358), mainly in connection with two possible factors: (a) pollination that failed because of weather conditions or incompatibility of the flower with its own pollen; (b) no fruit set because the ovules had failed in the gynoecium of the open flower.

This last factor is found more frequently with Congusta than with Robusta. For several Congusta clones the percentage of round beans in the consecutive months of the cropping period was determined. Although Congusta flowers through the year, there is a definite resting period from November until February, and it may be that reserved food is stored to be used for forming normal ovules. A comparison of fruits from the circumference of the trees with those from the interior did not show significant differences.

When the weights of the fresh berries and the market product obtained are compared, an unfavorable proportion is found with the hybrids which have C. arabica as a pollen parent. Such hybrids in a few cases double the number of chromosomes. It was in this way, that the better balanced and therefore fairly fertile Kawisari hybrids originated. Here the difference in chromosome numbers between the parents led to abnormal cell nuclei which form an obstruction for the normal development of the endosperm. It was thought that C. arabica, with its high number of chromosomes, might be a suitable pollinator. A case was reported in which a planting of Kawisari hybrid trees grafted over

with Congusta showed an increased yield. In view of this case Kawisari flowers were artificially crossed with pollen of Congusta and Kawisari, and the latter gave much better results. The Congusta pollen often gave a very low percentage of success, sometimes none at all, while with Kawisari the reverse was true. Cytological examination of endosperms showed that after pollination with Congusta nearly 80 per cent had too few chromosomes as compared with 37 after pollination with Kawisari pollen. The first kind of pollination gave 5 per cent normal beans, the second 10.3 per cent.

The influence of lack of cross-pollination on the occurrence of empty beans in Robusta was demonstrated when the percentages of empty beans in the consecutive rows near the border of another monoclonal planting were determined. The outer row of a special monoclonal planting showed 7 per cent empty beans, the third row 23, and rows farther in 25 (Ferwerda, 1935b, p. 505).

A note on hand pollination for crossing may be inserted here. A method of emasculating opening flower buds was described by Krug (1935) in Brazil, who used a small pair of scissors with notched blades. These cut through the corolla but not into the pistil. In Java the upper part of the corolla is removed by bending it sharply. It breaks and can be carefully removed by drawing it over the stigma. The very young fruits which show their shiny discs just after the flowering, do not all reach maturity. A certain percentage is thrown off by the trees. This phenomenon has been studied by Frahm-Leliveld (1940a).

POLYSPERMY

In contrast with these cases in which only one seed per berry is found, there are cases in which more than two seeds per fruit are formed. This "polyspermy" is characteristic and hereditary with a variety of C. arabica, the "many-seeded Menado coffee" (Burck, 1884 p. 53). The same variety seems to occur in Brazil, where it is called Hybrido-Redondo (Taschjian, 1932, p. 535). Polyspermy has been observed in Java in C. liberica (Koorders, 1901-1902, p. 357), and it was hereditary to some extent. In these there was only one seed per loculus. In polyspermic Menado each seed also has its own parchment skin. The origin of this form is obscure. The name suggests that it comes from Menado in the Celebes, but for a small planting once grown in the Cultuurtuin, seed was used which came from the Resident of Soerakarta (Verslag, 1873, p. 12; 1876, p. 18). A further generation in the Cultuurtuin consisted of some trees with polysperous fruit and others which could not be distinguished from normal C. arabica (Cramer, 1913, p. 199). The frequency of polyembryony or polyspermy in Menado coffee was mentioned as early as 1895 (Costerus and Smith, 1895, p. 118).

The "Coroa Coffee", described as producing berries with twelve seeds, may be a somewhat similar form. Specimens were obtained from Espirito Santo, Brazil, and forwarded to Kew, where they proved to belong to a fasciated form of Arabian coffee. The fasciation occurs in the shoots, flowers, and fruits, and it produces multiplication of the reproductive parts. The usual five stamens are increased to eleven, and numerous ovules are produced, giving rise to a corresponding increase of seed (Anon., Kew Bulletin, 1933, p. 413). According to Pennig (1921, p. 448), synanthly and syncarpy are fairly frequent, but the pistil was rarely trimerous (Baillon, 1880, vol. 7, p. 277).

Polyspermy in C. arabica has been described as characterized by fasciated branches, flowers, and fruit. Plants raised from seed obtained by autogecundation from such a tree, are entirely fasciated again. If crossed with the typical C. arabica, all kinds of intermediate forms are obtained (Krug, et al. 1939). Apparently this is the same form as the variety Coroa, different from polysperous Menado, which shows tricotely rather than fasciation in its vegetative parts.

Sometimes one seed may seem to contain more than one embryo which is then called "elephant beans" by the planters. As each embryo has its own integument, it is a case of "false polyembryony" (von Faber, 1912, p. 102), one loculus containing several seeds. Hille Ris Lambers found three embryos rolled up into one another in large round beans of Robusta and two endosperms next to one another in one loculus of a fruit of C. horgfieldiana. In 1895 Hanausek (1895) described diploembryonic seed of C. arabica and concluded from the fact that each component was wholly enveloped by cuticula that undoubtedly two independent endosperms were also present. Gandrup (1923, p. 102) who investigated the curving of the endosperm in the seed, came to the conclusion that the so-called polyembryony with Coffea was really polyspermy, that is more than one seed per loculus. He described a case with an illustration, in which three seeds were folded around one another.

Polyspermy and false polyembryony may be a clonal characteristic in C. robusta. For instance, polyspermy is typical for SA.75b (Hille Ris Lambers, 1938, p. 186).

CHAPTER 11
VEGETATIVE PROPAGATION

TECHNIQUE OF GRAFTING

For certain purposes coffee must be propagated by vegetative multiplication, by either grafting or by making cuttings strike roots. So far the first method has been by far the more important in Java and the rest of Indonesia, and it has become one of the routine planting techniques. A concise history of the introduction of grafting into the coffee planting industry of Indonesia was published by Ferwerda (1934, p. 192).

The credit for being the first to develop a practical method for grafting and applying it on a large scale belongs to a central Java planter, G. van Riemsdijk, who was manager of Klein Getas Estate. In 1900 he received well-merited praise (Anon., 1900-Ola, p. 147) for proving that grafting was practical on a large scale. The story was sketched by Kramers (1900, p. 535) in an excellent lecture at the Coffee Conference in Djocja on 8 November 1899. The new method was described with its improvements and its four objectives were defined concisely as follows: (a) To obtain trees with a nematode-resistant root system, (b) to multiply trees with the valuable characters not passed on by other means of multiplication, (c) to build up trees of desirable form, without the expense for upkeep and harvesting, and (4) to stimulate trees to greater and more regular production.

Kramer's views expressed 40 years ago on these four points are still valid in Indonesia, and he also gave a good sketch of the history of grafting. In 1888 van Riemsdijk made his first grafts at Klein Getas where leaf disease had forced the abandonment of C. arabica. Branch grafts 7 to 8 years old suffered heavily from Hemileia rust, and stem grafts of C. arabica on C. liberica 9 to 10 years old behaved exactly like regular Arabica seedlings, except that the union could still be seen. They suffered as much from the disease as ordinary C. arabica seedlings. Even though the objective of obtaining resistance in C. arabica was not attained, the experiments were successful horticulturally, inasmuch as they proved that grafting of coffee, even of C. arabica on C. liberica, could be successful (Kramers 1898, p. 91). Heavily attacked by leaf disease, the grafts just managed to survive. For a fair judgement of what could be realized by the new method it had to be tried under more favorable conditions. Since grafts or a hybrid at Klein Getas planted on a large scale showed luxuriant growth and heavy flowering, it was expected that under more suitable conditions C. arabica grafts would surpass seedlings. Grafting began to attract attention, and other estates started to experiment with it.

Grafting was widely discussed in the planters' periodical press of the day. In this connection the name of T. Ottolander should be mentioned. Some personal data on this leading figure in the Java planter's world may be found in Broersma (Besoeke, p. 135). Belonging to a family of nurserymen in Boskoop, Holland, he came out to Java to supervise grafting Cinchona, but he became involved in coffee planting. One of the first and most complete articles on grafting in the planters' press is from the pen of this gifted author, and here he discussed grafting from a general point of view and described the main points of coffee grafting in Java. Van Riemsdijk expressed in a letter to Ottolander in 1887 his desire to graft C. arabica on C. liberica, as the latter species could more easily acquire the necessary food from the soil from which the humus had disappeared than could C. arabica with its weaker root system. In June 1888 van Riemsdijk gave a lecture on his method of grafting. An optimistic report on young grafts of C. arabica on C. liberica was then published by Hagenaar (1890, p. 44). Afterwards little was heard about the subject until in 1896 renewed attention was given to grafting. The hybrids between C. arabica and C. liberica then attracted attention in Indonesia and also in the British colonies.

Van Riemsdijk made whip grafts "plakenten", in which both the stock and the scion were cut obliquely. This was well illustrated by Zimmermann (1901, p. 36). The scion was then attached to the stock so that it replaced the top, which was cut away. The grafts were originally made in nurseries and then transplanted to holes in soil 75 cm. deep and covered by a glass roof to keep the new grafts in a moist atmosphere until the union was complete. One man could make 120 to 200 grafts per day (see V. in Teymannia, 1896, p. 53). The glass frame was closed the first few days, and then it was gradually opened. After 21 to 25 days the grafts were transplanted to a nursery (Kramers, 1898, p. 91). That the method was practical was shown by the fact that many thousands of grafts of the Kalimas hybrid were made and used for laying out commercial fields on the estate. In 1888 it was reported that 53,000 grafts had been planted (Ottolander, 1936, p. 360). In 1896 this number had been increased to 140,000 (den Bouweester, cited by Ottolander, 1936, p. 360).

With such results as an example, several producing companies of Indonesia wanted to introduce grafting on a large scale into the routine work of the estate. With this in mind they engaged skilled nurserymen in Holland and sent them out to start the grafting on their Java estates and to improve the technique. One of these experts, Knepper, developed the method further. Grafting sheds

were built with double glass frames, and the work done under his supervision led to a very high percentage of success. In 1898 Knepper discussed in a lecture (1898, p. 102) various successful methods for grafting coffee and reported that results were excellent on all estates where the work was done carefully. Out of 1000 grafts not 5 failed to take root.

Of special interest was the result of a planting of 300 grafts of C. arabica on C. liberica at the Gangsiran Estate. The stocks were 6 years old at the time and had yielded an abundant crop for two years. According to a planter named Vogler (1899-1900, p. 310) growth of a small number of grafts was satisfactory, but very backward compared to that of seedlings and in many the primary branches died. It seemed probable that C. liberica was not a suitable stock for C. arabica.

In 1898 Kramers visited the estates and found planters optimistic about grafting C. arabica on C. liberica, but a year afterwards their mood had changed. Many of the grafts planted had not grown and the percentage of thrifty ones was very small. He attributed part of this failure to lack of experience, but was more certain that the main cause was the difficulty involved in making C. arabica grow together with C. liberica.

When old grafts were cut through it could be seen that the union was far from perfect, while with the hybrids, stock and scion grew together well. A serious attempt was made to improve the union by grafts with hybrid scions on C. liberica. Simultaneously this scion was grafted with C. arabica so as to join the two kinds through the hybrid as intermediary. However, such grafts were neither better nor worse than the original grafts.

Other methods of grafting have been tried. Krijthe successfully grafted young seedlings in the kepelan stage by causing them to adhere to one another ("plakzoogenten"), a procedure reported by Kramers (Teysmannia, 1900, p. 597). This method has disappeared, probably because it is of no use with hybrids, where the scion has to come from the original tree. However, later the method was recommended for providing C. robusta seedlings with a double root system, combining the seedling's own root and a C. excelsa root which was thought to increase the resistance to nematodes.

The grafting of young seedlings by approach and grafting directly on the root were described by Gandrup (1936, p. 1082). His plan was to graft a clone on to a growing seedling root. With root grafts young seedling tops were placed on a root taken from an older tree so that in this way the root system of a chosen tree was propagated vegetatively, to develop what might be called a "root clone". Afterwards a clone could be grafted on the seedling so that the end product was a plant composed of a root of a given tree, an intermediate section made of a seedling, serving as a joint, and a top of a clone.

It is curious to note that in Indonesia shield budding never became popular among coffee planters. Wester (1922, p. 63) tried this method in the Philippines with coffee and was successful when he used well matured, green, non-petioled budwood with buds from 3.5 to 4 cm. long. The buds had to be entirely covered with waxed tape. The advantage of this method of propagation was that two buds per node were obtained, and thus the propagation carried out more rapidly. He found shield budding on coffee seedlings two or more years old was impractical because the bark was too brittle. The budding of coffee was also described by Galang (1928, p. 360).

GRAFTING UNDER TUBES

A technician named Butin Schaap was responsible for a great improvement. He made cleft grafts of Maragipe, an arabian mutation onto vigorous, healthy young C. liberica plants, two years in the field and already carrying branches. Tops of shoots were used as scions and the leaves trimmed, leaving only a small part near the petiole. Afterwards the scion was cut lower down from the shoot, where it began to become woody. A small piece with only one node, about in the middle, was sufficient. After the graft was tied a glass test tube was put over it. Butin Schaap stressed careful choice of stocks. He found that vigorous C. liberica plants should be used, and the cleft graft should be made at about 4 feet above soil level. The branches of the stock were left at first and only gradually removed (van Laer, 1904-1905, p. 97). In the beginning a fair degree of success was realized, a fact all the more striking inasmuch as Maragipe is even more difficult to graft than typical C. arabica (Kramers, loc. cit., p. 564). He realized very well the advantages of the method for it could be used in the field on young and old trees alike and did not require a grafting shed. A successful case was described by Heijden (1899-1900, p. 1239). One grafter could easily make 200 to 225 grafts a day. In those days Everard used the cleft grafting system on a large scale in Kawisari to convert his deteriorated, poorly yielding plantings of C. liberica into flourishing fields of hybrids (Cramer, 1923, 1924, p. 570).

If Butin Schaap's method of grafting was applied about 1900 on other estates with coffee hybrids and proved to be a success there, this was not the case when the combination of the pure species was tried. In 1901 a planter in east Java described how he tried at first to make copulations of C. arabica on C. liberica. After a preliminary success the plants died when 4 years old. The

Butin Schaap's method was tried. The development was excellent in the first 6 months, but grafts started to droop and died after about 18 months. No planters in the district had any better results (Punter, 1901-1902, p. 119).

On Butin Schaap's estate the preliminary results of the Margogipe grafts on Liberian coffee were very good. Zimmermann (1901a, p. 632) mentions grafts of Arabian which bore 1414 to 1685 berries when 12 to 14 months old and Maragogipe grafts of the same age with 980 to 1,020 berries. A very favorable report on Butin Schaap's plantings of grafts was published after a personal visit by Preyer (1901, p. 494).

Butin Schaap (1901, p. 220) noted his good results, and that the failures elsewhere may have been caused by grafting on plants which were too young. He held that Liberica plants of a height of 1.20 to 1.40 meters should be used. Afterwards Butin Schaap sent photographs of grafts ranging from 18 to 24 months in age to the editor of the planters' periodical, who recommended that the planters' association make an investigation of the problem (Anon., 1901-1902, p. 285). Very soon two well known planters, T. Ottolander and A. de Stoppelaar, were delegated by the board of the Syndikaat to report on the grafts at Kandangan (Ottolander, 1936, p. 360), Butin Schaap's estate. This was so that the controversy between the scientists, who reported favorably on the results after a visit to the state, and the planters, who tried the method, might be cleared up.

Ottolander described what was shown to him during a visit to the estate. Grafts were on C. liberica stocks of 1, 2, 3, 4, 5, and 18 years of age. The grafts were top and branch grafts of C. arabica, of Maragogipe, and of Erecta a variety of C. arabica. There were also some grafted on hybrid stock and on Margogipe stock. The branch grafts were not very good. The top grafts were better, but strongly influenced by the stocks. On one year old stock they were not particularly remarkable, on two year old stock better, and on 3 to 5 year old stock frequently splendid. Grafts ranging from six months to 3 years in age on 4 to 5 year old C. liberica were very good. The 3 year old grafts had already produced. Some suffered from overbearing, just as seedlings would have done, but the majority were well along with flower buds. Ottolander discovered that Maragogipe was better for grafting than typical arabian, as apparently grafting stimulated production, while Maragogipe alone is inclined to a low yield, a fault that was corrected by grafting. On the other hand, there were signs of overbearing in C. arabica. Ottolander argued that the success could not be ascribed wholly to the method used, although the method might be responsible for the number of takes. The further growth of the grafts depended on another factor, the stock, especially its age, condition, and subsequent care. Ottolander added a few notes on results from grafts on his own estate of varieties of C. arabica on stock of Typica, Maragogipe, Laurina, and Mokka. The grafts on the last two varieties, which have a weaker growth, showed a less favorable development. Of the scions, Maragogipe grew better than Typica, and Erecta grew still better. On another estate it was found difficult to establish plantings with grafts made in the nursery on C. liberica, and out of 100 hardly 10 showed satisfactory growth. Neither did C. liberica do too well on C. liberica. The first year growth was poor, and improved only in the second year. Hybrids did better, although seedlings of hybrids were unreliable.

Attempts to graft C. arabica on C. liberica were not fully successful. From the fact that it was never applied on a large scale we may conclude that the results were not satisfactory in the long run, and it seems doubtful whether a solution would have been found even with further experiments.

Butin Schaap's method of cleft grafting under tubes attracted a good deal of attention. A complete, well illustrated description of it was published by Zimmermann in 1901 in which he also studied the anatomy of the union. It seems, however, to have failed as a method for grafting C. arabica on C. liberica, for little ever has been heard of the older grafts. When the Bangelan Station was started, experiments on grafting were instituted, and serious studies were again made of Butin Schaap's method of grafting.

Materials of Typica and Maragogipe on C. liberica were included in the technique studies at the station. The annual reports of the first years contain data on these grafts, a story of difficulties and failures. Various combinations and different methods were tried. They were enumerated, and the poor results, which were ascribed to climatic conditions, were cited in the report for 1905 together with the conclusion that no further experiments should be conducted (Jaarverslag, 1905, p. 119-121). It was only about a decade later that grafting was resumed at Bangelan and then with success.

On Kandangan Estate itself, Butin Schaap's estate, there were 65,000 grafts in 1904. The oldest were than five years old (van Laer, 1904, 1905, p. 98). However Arabica grafts on Liberica never became popular. Apparently the difficult union between the two species was again here the main obstacle. Attempts to graft C. liberica on C. liberica stock also met with little success (Kramers, Teysmannia, 1899, p. 567). Better results of grafts of these were discussed by MacGillavry

and other planters at a conference in 1903, but large scale application did not seem to have been undertaken.

FURTHER DEVELOPMENT

Butin Schaap's method of cleft grafting of robustoid coffees under tubes, gradually became, with some slight modifications, the most popular one, but the van Riemsdijk method also continued to be used. In 1910, Bangelan still used a grafting shed (Gorter, 1910, p. 31). The Butin Schaap method of grafting was improved by replacing glass tubes with old newspapers molded on a test tube and soaked in paraffin wax. These were much cheaper and not subject to breakage and theft.

The wax paper tubes (Ultee, 1928b, p. 29) were made of a strong piece of paper about 15 cm. square, wrapped around a common glass grafting tube. The paper was tied at the top and glued at the side, and the top then dipped in paraffin wax, then the lower half. The percentage of success under these tubes was as high as under glass tubes, but care had to be taken that the cut surface of the scion did not touch the tube, as it often caused dieback. De Haan (1923b, p. 22) stated that on the Petong Omboh Estate, tubes were made of parchment paper sown together, while the grafts themselves were whip grafts similar to those of van Riemsdijk. Slight modifications in the technique were tried by Gerretsen (1935, p. 978), who took young plants from the nursery, grafted them, kept them one night in a moist atmosphere, and planted them the following morning, thus obtaining a high percentage of success. Direct grafting on old trees was also successful.

Good descriptions of the current technique and practical hints were given by Wurth (1915, p. 880) van Helten (1915, p. 7), and de Haan (1923b, p. 18). A special technique for making grafts of the hypocotyl of young plants, of the young stem, and of the hypocotyl with part of the root of young seedlings, was described by Ament (1936, p. 1). The stocks used were lateral roots of the same diameter as the scion. By this system grafts could be placed on root systems of known characteristics, for instance, roots with a high nematode resistance. Very high percentages of success were obtained. With the use of glass tubes the success was often complete. For experimental study such grafts could later be re-grafted with graftwood of a mother tree, and thus this tree placed on a root of known characteristics. However, according to a later report by Roelofsen & Coolhaas (1939, p. 92), the grafts which were planted showed a tendency to fall over. Ament's clever method of grafting seems to be more suitable for experimental work than for estate technique.

At present grafting is simplified by the use of grafting wax. If all the wounds, including parts where leaves or branches have been cut, are protected against drying by smearing with some grafting wax, grafting tubes are superfluous. Such a grafting wax can be made with 20 kg. resin, boiled in a tin, to which 0.5 kg. of yellow wax is added. After the mixture is boiled well, 100 cc. of linseed oil is added. The mixture is then allowed to cool under continuous stirring as water is sprinkled into it. When it has cooled somewhat, it is poured into water and is then ready for use. Certain proprietary products have been used successfully, but they must be used with care, since on estates in lower altitudes they may, if exposed to direct sunlight, melt and penetrate between stock and scion.

Another special way of grafting was discovered by Hille Ris Lambers (1935b, p. 1457). He tried to unite young seedlings still bearing the cotyledons, with shoots on coffee trees. The hypocotyl portion, the stem under the cotyledons, was placed on the shoot as a side graft, and the graft was then tied and covered with a little paraffin wax. This was done on 3 November 1933. The grafts soon took and were much in advance by comparison with plants kept in the nursery. By June 1934 they had already developed primary branches. They flowered on 15 September, less than a year old, and in August 1935 the first berries ripened, about two years after the seed had been planted. Similar grafts made on primary branches were also successful. He also referred to a method applied by Cramer one year before by grafting the top of young plants on shoots of old trees. He obtained in this way ripe fruit three years after planting the original seed, about one year less than when the natural process was followed. The method of Hille Ris Lambers meant again in time of two years, but if the graft fails, the young seedling is lost.

An excellent review of the literature on the technique of grafting by Feilden G. St. Clair in 1940 has been published by the Imperial Bureau of Horticulture and Plantation Crops, East Malling, Kent, England. A large amount of information was collected from all coffee growing countries and synthesised, giving proper treatment to each detail. The data relate to all different kinds of coffee. The data from Kenya, Tanganyika, and Mysore relate mainly to *C. arabica*, the principal kind grown in those countries. It was evident in various experiments at the Scoot Agricultural Laboratories, Kenya, that *C. arabica* grafted on various varieties of it grew well, while *C. arabica* on *C. eugenioides* produced a dwarfed and sickly tree. Arabian on Robusta produced a tree susceptible to drought, a circumstance attributed to the shallow root system of the latter species. Not one of the many indigenous and imported plants of the order Rubiaceae was found to be compatible

with coffee.

As we have already noted in Indonesia the grafting of hybrids was found quite practical as routine work on estates. Not only Klein Getas estate laid out large commercial plantings, but about 1900 Everard on Kawisari estate applied the Butin Schaap method to the hybrids which bear the name of this estate. Many estates in east Java also made small plantings of hybrids. It can readily be understood why planters also tried grafting with Robusta when it appeared on the scene. It turned out to be possible to use it as a scion, but at that time no need was felt for this complicated method of multiplication, for seed was available in quantity. Moreover, in contrast with hybrids, seedlings produced excellent commercial plantings. How little progress the application of grafting made in the coffee planting industry and how it was only adopted when necessary, is best revealed by a remark of De Haan (1923b, p. 4 et seqq.): the main reasons why horticulture has had recourse to grafting were (a) the possibility of placing plants with weak roots on a more vigorous stock, and (b) the possibility of multiplying plants difficult to propagate by seed in large numbers.

Sometimes in a nursery a large percentage of grafts have died which had taken and even achieved some growth. One planter reported a case in which only 10 to 20 per cent lived. In this case, before the graft was made the top of the young plant had been cut, the stem cleaned, and the leaves removed. Later this method was modified, and the leaves were left on the stock. The success was then 90 to 100 per cent (Mulder, 1937, p. 1371). A similar experience was described by Leser (1937, p. 1709), who added that he had been most successful in grafting in May at the beginning of the dry season and that the stocks were left open a day or two after the cutting of the top.

ADVANTAGES OF GRAFTING

Grafting on a large scale in coffee culture was placed on quite a different basis by the experiments conducted at Bangelan (Cramer, 1924, p. 86). I had been given the supervision of Bangelan in 1941, and grafting was put at the top of the agenda. It was felt necessary to establish a living museum of small sets of grafts of superior trees, but also with much wider possibilities in view (Cramer, 1934, p. 202) "if Bangelan could push the planting industry further in the direction of vegetative multiplication, it would be doing the most useful possible work at present". (Cited in Cramer, Oude verkrijzen, 1923-24, p. 633). This statement conformed to my conviction (ibid, p. 606) that the introduction of large scale application of vegetative multiplication in tropical agriculture would be one of the best means to bring the permanent crops to greater prosperity. The whole situation of grafting in the industry was reviewed in 1923. Up until then vegetative multiplication had only been used when it was absolutely necessary, as with coffee hybrids. But now it was planned to use it for establishing fields of various kinds of coffee generally multiplied by seed.

A bread and, for those days, daring program, was aimed at laying out commercial plantings composed of monoclonal blocks of superior types of Robusta and other species. This had been planned in 1914 to learn something about its advantages and difficulties. The execution of this program took from 1914 until 1919. It comprised work in nurseries as well as grafting over old fields (loc. cit., 1923, p. 633). The results were everything that had been expected. The experiment brought out the advantages stemming from the great uniformity of all the trees composing the planting. These may be grouped under five headings: uniformity (1) of growth and further stand; (2) of individual production and (3) of fitness for multiplication by grafting; (4) of crop and product, and most important of all, (5) of time characteristics (1924a, p. 76). For (1) and (2) some data based on experience are noted. In connection with (3) it had been found that even among seedlings of the same mother tree one is likely to take more easily as graft than the other, and that the further grafts repeat this greater or lesser fitness for multiplication by grafting. The uniformity in size of the berries makes the curing easier and the market product more attractive, but the greater advantage is (5), the uniformity of time characteristics. The concentration of the ripening period of the crop for grafts is shown in numerical terms. The main crop ripens in two or three months, but for various clones these months are different. For instance R. Bgn.59.01.01, they are May-August, for 59.01 May-July, for Bgn.105.11 July-September.

This not only makes the picking cheaper, but it is also important inasmuch as it enables the planter to fight the berry borer much more effectively, a point to which Schweiser attributed special importance in his study on combatting the berry borer (1925b, p. 287). Cramer (1927, p. 143) thought of the possibility of arranging estate plantings with monoclonal plantings that had successive ripening periods so that the crop would come in regularly from the different parts of the estate and thus avoid an excessive peak load for the factory. A further advantage of a policy of planting an estate with early, middle, and late flowering clones would be that there would be not one, but several flowerings per year, thus dividing the risk (de Haan, 1923, p. 58).

It was not possible to give a definite answer whether seedlings or grafts of robustoid types should be preferred as planting material. When new land was to be opened it can be understood that

the preference still went to seedlings, especially of the carefully studied and tested high grade clonal families. For special cases, however, for replanting and for supplying, practical planters recommended grafts. With grafts in Indonesia, growers could be more certain about the qualities of the material and could combine desirable characteristics of the root system with other characteristics of the clone. On several occasions de Stoppelaar advocated the use of grafts under difficult conditions.

In a discussion of the question of planting distance de Stoppelaar (discussed in de Lig, 1936a, p. 21) said that he thought that on soils long under cultivation it was more difficult to obtain a new planting from seedlings, for the many diseases and pests of Robusta forced the planter to use grafts on a good stock. A more general view of the dilemma was given by Hille Ris Lambers (1937a, p. 985), who answered the question of whether grafts or seedlings would be preferable in the long run by saying that a final answer will never be given, since the competition will continue on a higher and higher level. Among superior seedlings superior clones will be chosen. Crossings of these superior clones will help us to secure new seedlings, and thus the competition will continue. Something similar has long been seen in the budgrafting of rubber. As van den Abeele (1938, p. 139) justly remarked, when the vegetative multiplication of coffee is compared with that of Hevea, the two main difficulties are the more limited supply of grafting wood and the greater importance of choosing the most suitable stock, although on the last point with Hevea the final word has not yet been spoken. Very poor results such as those found with some combinations in coffee (Cramer, 1928, p. 25) are not encountered in Hevea budding.

THE STOCK PROBLEM

In connection with what was learned about the difficulties in the experiments on grafting at Bangelan it may be observed that often grafts of superior Robusta trees, when grafted on Excelsoid stock, were deceptive. There were, however, exceptions. They took well, and the deceptions came after they had ripened their first crop. Although the yield was not at all high, they had apparently suffered from producing it and showed signs of "overbearing". This was true to a much slighter degree with grafts on robustoid stocks. To study this problem further a series of experiments on various combinations of stock and clone was planned, and the results began to come in about 1928 (Cramer, 1928, p. 5). These experiments showed the value of the seedlings of the Robusta Bgn.124.01 as a stock, a number that is still a favorite for this purpose. It is, however, not a universal success as a stock. De Stoppelaar (1936a, p. 315) found it wholly unsuitable for his estate and in the course of his remarks noted that "several seedling families of Excelsa, Quillou, and Canephora" did especially well there as stocks.

In the discussion, various experiences with Bgn.124.01 on neighboring estates were mentioned (p. 318). Other popular robustoid seedling families for stocks were found to be SA.109, Canephora Madagascar 3 Bgn., and Quillou Bgn.121 (Gandrup, 1934, p. 222). Pure Robusta seedlings were also included in Cramer's (1928, p. 25) experiments. Robusta Bgn.59 seedlings gave poor results as stocks, even when grafted with Robusta Bgn.59.01, a combination in which the clone and the stock contained the same "blood" which was said to be a favorable factor. In later years an experiment with Robusta stocks, grafted with Robusta clones, showed only small differences between Bgn.59.01 and Bgn.124.01 grafted with pure robusta (Ament & Gandrup, 1934, p. 577). In Cramer's (1928, p. 47) experiments, grafts of the liberoid hybrid, Kawisari, were compared on C. excelsa as stock with grafts on Robustas Bgn.124.01 and Bgn.59.01. The results on 124.01 were best, while the reverse would be expected in view of the apparently closer relation between that hybrid with C. excelsa than with C. robusta.

Several Robusta clones were tested on various seedling families by Schweiser & s'Jacob (1938, p. 1526) comprising well known families such as: Bgn.124.01, SA.109, BP.42, the C. excelsa numbers recommended by Ferwerda, a few C. dewevrei families, and C. arabica. C. dewevrei was included as those seedlings did better than C. excelsa on nematode-infested soil. While many of the grafts took well, this was not the case with the grafts on C. dewevrei. After a year and a half the lengths of these were measured. Many of the plants had to be replaced, and many remained backward. The union was abnormal in many C. excelsa plants. It was plain that the C. robusta stocks gave the best results. Among these combinations BP.4 and 39 were the best on seedlings BP.4 while BP.25 was the best on Bgn.124.01, and BP.42 was the best on seedlings of BP.42. In another test, some of the same stocks were used, and seedling of an Excelsa x Liberica hybrid were added. The results were similar.

Schweiser & s'Jacob (1938) warned against use of untested families for stocks and concluded that Robusta stocks were more suitable for Robusta clones. A curious fact was that on C. excelsa hybrids, grafting gave high percentages of preliminary success, and the trouble appeared only after 8 to 10 months. Some hybrids of C. arabica x C. robusta when grafted on these C. excelsa hybrids died after 1 to 3 years. Others languished away but lived. When the plants died, the graft died first and then the stock.

As early as 1930 C. excelsa had lost favor with the planters as a stock for C. robusta grafting (Hille Ris Lambers, 1930a, p. 548). Some very interesting experiments with grafts of Arabica on various stocks in Java, have already been mentioned above. With experiments on grafting in the Philippines in which cleft grafting as well as rind grafting was applied, C. excelsa was found to be a better stock than C. quillou (Romero, 1930, p. 62). From his work it is clear that C. quillou succeeds better on C. excelsa than C. excelsa on C. quillou. C. liberica succeeded on C. excelsa better than on C. quillou.

In Indonesia, Hille Ris Lambers (1931a, p. 687) observed the bad results of C. excelsa as a stock, as the stock and scion did not unite well. However, in a discussion of the value of C. excelsa coffee he nevertheless later mentioned it as a stock for grafting (Notulen, 1934, p. 1021). It should be noted that C. excelsa grows well on soils not suitable for C. robusta and is more resistant to drought. It suffers less from nematodes, but the degree of attack are about the same as with Robusta. Seedlings of the clones Bgn.121.04, 121.10, and 121.02 were recommended as stock.

Planters cited various experiences with the suitability of C. excelsa as a stock for C. robusta. Only certain C. robusta clones, mostly large-branched ones, did well on C. excelsa. Hille Ris Lambers mentioned that among the variable seedlings of C. excelsa a certain number were suitable for grafting with C. robusta, and among these clones a group were also suitable for such a combination (loc. cit., p. 1023). Later field experiments confirmed that for the various C. robusta clones vigorous C. robusta seedlings as stock gave better results than C. excelsa stocks (Coolhaas, 1939a, p. 559). About the same time s'Jacob & Hille Ris Lambers (1938, p. 44) gave the following explanation: C. excelsa appeared more drought-resistant than C. robusta, a fact attributed to the leathery leaves. It might be attacked by nematodes, just as C. robusta but the loss of part of the root system affected the tree less.

If a C. robusta graft was placed on the root system of a C. excelsa, it did not retain much nematode resistance, as several tests of C. robusta clones on excelsoid and robustoid stocks have proved. The authors laid stress on the greater influence of the vigor of the graft on the growth than that of the stock. It was observed by Hille Ris Lambers (1938a, p. 1275) that C. quillou, used as stock, presented the advantage of being a quick grower, but this advantage could only make itself felt when a vigorously growing clone was grafted onto this stock.

Somewhat different conclusions were reported by Ferwerda (1935a, p. 432). A set of seedlings intended for grafting were classified into slow, medium and quick growing plants, and all grafted with Robusta Bgn.78.11. When the success of the grafting, the number of losses in the field, and the rate of growth of the successful grafts were later compared, no difference between the classes of stocks was found. Seedlings grafts were put on three seedling families: Robusta on Bgn.124.01, on Excelsa Bgn.118 and on Canephora Bgn.20. The lowest percentage of losses after the planting in the field occurred with the grafts on C. excelsa. The growth in length was greatest on Canephora 20, the last stock. Congustas 4 and 161 succeeded much better on C. excelsa than on C. robusta, where a large percentage died about two months after the grafting. Similar observations were made by de Ligt (1936, p. 154). C. arabica, which did not show vigorous growth on his estate, developed a much better root system when grafted with C. robusta or C. congusta than when left ungrafted. C. quillou under C. congusta grafts was even better.

In the Ivory Coast of French West Africa, grafts have been made of C. arabica on C. robusta and on Indénié, a strain of C. liberica. The percentage of success on the latter was higher and the growth more rapid (Poupart, 1938, p. 170-171). In Indonesia, Hille Ris Lambers (1929, p. 36) was successful in grafting C. arabica on C. horafieldiana, but not in grafting coffee on Ixora or the reverse combination. The possibility of grafting true coffees on a related Rubiaceae, the so-called Coffea schumanniana, that is in reality a species of Psychotria, will be discussed later.

Grafts are generally made in the nursery on seedlings about one year old. De Stoppelaar (1937, p. 347) used older seedlings and made branch grafts with several clones which succeeded very well. Later the method was successfully applied on a large scale. The best kinds of shoots for grafting have been studied by de Graaf (1941, p. 1195), who experimented with shoots of old trees, treated with sector pruning, with shoots of old trees, stumped at 1 - 1½ meters, with shoots at the top of 3 year old trees in a replanting, and with shoots on 2 year old stumped plants in the nursery. The grafts on old trees treated with sector pruning showed the quickest growth; top grafts on stumped nursery plants remained backward, compared with grafts on low shoots of old trees. The growth on 3 year old trees depended on the state of the trees. Special fan grafts of numbers, like TP.21 and BP.42, were the best for giving deteriorated trees a new start. No influence was found on grafts starting flowers. Young plants were also tried one week after transplanting. Of 30 grafts of the pretreated graftwood of SA.109, a total of 28 were successful.

CHOICE OF GRAFTING WOOD

If the experiments at Bangelan have drawn attention to the problem of stock for coffee, the problem of the most suitable grafting wood for scions has also been studied for several years. Only two kinds of graftwood were used. These were shoots from the main and branches, preferably oblique branches. Van Riemdijk preferred branches as grafting wood for the Kalimas hybrid, since stem-forming grafts developed *Hemileia* rust. Everard did not encounter this difficulty with the Kawisari hybrids and went in for stem grafts. A similar case was found in Robusta at Kaliwining by the Besuki Institute. While stem grafts of most clones grew well, KW.18, the clone with the largest beans, could only be used for branch grafts, as the stem grafts suffered too much from branch borer. If the graftwood was taken from primary or oblique branches, bushy, semi-erect trees were obtained. If dorsiventral secondary branches were used, the grafts did not develop a stem but remained nearly horizontal, forming the so-called "crow's nests" a much less desirable growth habit (Hille Ris Lambers, 1935c, p. 366). In an experiment on the use of plagiotropic graftwood from young plants, the grafts produced normal branch grafts (de Haan, 1923b, p. 14).

At an early date a planter, A.B. Houtsmuller, drew attention to the use of grafting wood from branches (Hille Ris Lambers, 1933a, p. 595), and a good deal of attention was then given to the choice of the proper wood (Hille Ris Lambers, 1937a, p. 988; 1939, p. 70, Meyer, 1939, p. 59, Coolhaas, 1939, p. 47, and Schweiser, 1939, p. 954). The first part of Meyer's articles gave a description of the way branches and shoots developed, a phenomenon which he spoke of as the different "gradations" of wood. He called the serial buds in the leaf axils on the primary wood "primary reproduction buds". Only the upper bud, generally moved up slightly above the serial buds, was called a secondary or "legitimate bud". He also described the various kinds of top budwood of branch budwood. Hille Ris Lambers compared branch grafts developed from different kinds of grafting wood of the same clone, for instance (a) an oblique, upward branch and (b) a typical dorsiventral branch. The internodia cut from the main branch (a) gave grafts with an oblique upward growth, and those of (b) gave grafts of a flat growth. In both cases the grafts showed a strong frame of 4 branches. If internodia of the lateral branches of both kinds of graftwood were used, no regular frame was obtained, but there was an irregular growth of thin branches.

Various correlations were found between the mean length of the 3 longest branches of the grafts and the girth of the stock, the angle under which they grew, and other characteristics. Coolhaas gave an introduction to both articles and stressed the importance of choosing the right graftwood. Internodia cut from the main branch of a fan branch gave branches with the greatest vigor and were especially suitable for rejuvenating old deteriorated trees. Internodia of whip branches gave grafts with productive, pliable, but less vigorous branches. Unfortunately, the authors developed a rather complicated terminology for the various kinds of buds and branches, and this fact made it difficult to determine the point from which the budwood could be cut. This may be made clearer by understanding the branching habit of coffee, particularly of the Robusta tree.

In such a tree that is young, the stem bears "primary branches" which are formed at the top of the tree. The growing point forms the internodes prolonging the stem, and the two buds next to it form the primary branches. If they have once sprouted, a later pair of primaries may come from the point of origin of the primary branches, imitating the development of the main stem, which they may reproduce if necessary. Under the base of the primary branch there is a series of "serial" or "reproductive" buds that produce suckers. If the main stem is topped, these reproduction buds are forced to develop many shoots.

The presence of the serial buds, generally about 5, in the axil of a leaf was early described by de Haan (1923a, p. 90). The upper one, called the legitimate bud by Meyer, usually forms a lateral plagiotropic branch or primary branch, while the others, if they sprout, give orthotropic suckers. Normal plagiotropic branches grew horizontally while the orthotropic growths grow upwards. De Haan thought it probable that the available space was the decisive factor determining whether or not the buds of either type would sprout.

When the primary branch in Robusta grows further it does not, like the stem, develop branches from the growing point, but it only forms further internodes. Later on branches grew out from the primary branch, and they are comparable with the shoots on the stem. Like these they follow the same direction as the element from which they develop, and they can be formed again and again, originating like the shoots from serial buds. Cutting the mother branch stimulated their development, and they are called "reproduction wood". When the original primary branch dies, they take over its function, and then they die and are replaced by others. They form the greatest part of the fruit-bearing wood of a Robusta tree. All these branches, including the primary branches, are called the "whip branches".

Under certain conditions the growing point of the primary branch can form, like the growing point of the stem, with the internodes prolonging the branch, two sidebranches simultaneously, com-

parable with the formation of the primary branches by the growing point of the stem. When this formation is repeated several times by the growing point of the branch, several successive pairs of branches originate, and they are called legitimate or secondary branches. The whole, the primary branch with its secondaries, is called "a fan branch". Only one pair of secondary branches can be formed per node. The buds from which they sprout are at every node, but they generally remain dormant, except, as we have noted, on the fan branches. If these buds, there are 2 per node, have once sprouted into the secondary branches, no more can be formed at the same node. It is characteristic of the secondary branches that they do not produce reproduction wood easily and that they never do form tertiary branches at their growing point. They are the ultimate "wood gradation".

The tendency to form secondary branches -- and thus to grow fanlike -- must be attributed to a stimulant of which nothing is known. This tendency is sometimes called "potency" of the branch, and in Robustoid coffees, it can be influenced by pruning and grafting wood, but is ultimately a clonal character. There are all kinds of transitions between the reproduction branch which does not "fan" (no potency) and the one which "fans" completely (absolute potency). There are reproduction branches on which the buds intended for growing into secondary branches have already swollen without sprouting; and in this case it may be said that the potency has been increased. Sometimes only one of the two secondary buds has grown out to a secondary branch, or the pairs of these latter branches alternate with open spaces. In such cases the term "incomplete fan branches" is used. To this kind also belongs the reproduction branch, which forms only internodes at first, and only at its top, internodes with secondary branches.

The two different kinds of grafting wood -- fan branches and whip branches -- give different growth to the graft. The frame of the fan branch grafts consists generally of a few rather erect fan branches, which, if they do not bend down, form their fruiting wood further and further from the stem. The growth is more vigorous, and this factor has a favorable, rejuvenating influence on the stock. There is a relation between the angle at which the branches sprout and this rejuvenating value. A quick formation of vigorous fan branches, which is symptomatic of a great rejuvenating power, is always connected with a fairly steep direction of these branches. The use of fan branches is, therefore, indicated when new life has to be given to deteriorated old trees by grafting them in the field. The whip branch has the advantage of assuring a definite optimum yield per hectare as a result of the small space occupied per graft. It is well suited for selective field grafting, where healthy, vigorous trees with a poor yielding capacity in fairly complete plantings have to be grafted. The difference between this and the top grafts is that the latter bears on the primary wood while the whip branch graft bears on the reproduction wood of the primary branches.

The fan branch grafts offer more problems. Clonal characteristics may play an important role. For example fan branch grafts of Robusta TP.21 give excellent results not only because of their strong rejuvenative power but also because of their capacity to yield. They form new fan branches at a rather steep angle, but these branches bend down. Still better types are expected from new crossings, for instance, TP.21 x BP.42 x Congusta SA.36. Fan Branches of Congusta generally bend easily. In lower regions the quicker growth produces bending branches in the same clone. The tendency of fan branch grafts to become empty in the center can be corrected by a pruning aimed at pushing back the formation of yielding branches towards the center of the tree.

When the grafting wood is cut it should be selected in accordance with the type of grafts intended to be applied. First if a fan branch graft is desired, internodes of a fan branch are used that are as complete as possible. Secondary branches, which are cut before the wood is used, should already have been formed. Such an internode can no longer form secondary branches, for it has to develop reproduction wood or further fan branches. Second, if a whip branch graft is desired, primary branches or reproduction branches of top grafts can be used and also whip branches of other branch grafts, if they do not show increased potency by the presence of swollen secondary buds. Internodes can be chosen on which the serial buds are swollen, a condition which insures quick sprouting.

The great value of branch grafts is their use for selective grafting in the field, for removing the vigor of deteriorated trees, and for increasing the yielding capacity of vigorous but poor yielding trees. All of this brings the planting to a higher yield level. If a planting of Robusta is to be wholly rejuvenated, top grafts are preferred, since much more experience on this kind of materials is available and since its use allows low stumping.

The use of a special terminology in the original articles on the choice of grafting would not pass without criticism. Some points discussed by other research workers may be summarized here. The main objection was that the general botanical literature on the subject was not taken into account. If this literature had been consulted, the whole development of the stem and branches could be described in a much simpler manner. For example distinction could be made readily between "familial" and "adventive" buds. The first were known to originate in the leaf axils, often as a series of buds. The uppermost of these serial buds were often numbered (1), the next (2), and so on.

ber 1 would be found to be the first to sprout, and the following ones often kept back by growing substances coming from the growing tip.

A top shoot may show a central bud with two upper serial buds which are then influenced by the central bud in such a way that they show a plagiotropic development. If this influence is still stronger, the serial bud does not sprout at all; but by the strong growth of the shoot the upper serial bud and sometimes the second one as well is moved a few millimeters above the leaf axil, thus lending them the appearance of adventive buds. Their origin shows, however, that they are axillary buds. Although the axillary buds no. 1 and no. 2 grow differently, no. 1 being a branch and no. 2 a shoot, their similarity can be proved by cutting away the central bud in a young stage. Then no. 1 bud also forms a shoot similar to no. 2. Therefore all buds basically are reproduction buds.

The difference between laterals and shoots may be summarized by the following points: 1) In the lateral, the orthotropy of the original bud is suppressed. 2) In the lateral, the tendency of the shoot to form two branches together with the leaves at the growing point that is also suppressed. 3) This suppression takes place during the simultaneous sprouting of the top and axillary buds no. 1. However, under favorable conditions both suppressed capacities may gradually come back, the second one more easily than the first. When the latter has come back, the result is the fan branch. When this branch grows more and more erect, the second capacity comes back and the growth acquires the form of a top shoot.

The same applies to the buds of a branch. If the axillary buds sprout simultaneously with the terminal buds, then their capacity for "fanning" and for orthotropic growth is suppressed still more. When they sprout without being influenced by a growing terminal bud, they reproduce the branch. It is not a question of the loss of capacity, but of suppression of capacity, of a broken equilibrium, as is proved by the gradual return of latent capacities. At first a lateral develops sporadically, a few branches simultaneously with the terminal bud and later on more, until the fan appears. It shows a gradual tendency to orthotropic growth until the shoot characteristics are restored. With some clones the oblique fan branches become orthotropic fairly soon, and when nodes from them are grafted, they develop into normal top grafts. If orthotropic fan branches are used again from this source, a top graft is obtained once more. Therefore the classification into various "gradations" as primary, secondary, etc., should be dropped. In this critique the remarks on the gradual change of the character of a branch into orthotropic would seem to have a special value.

In some clones, graftwood has flower buds which develop their flowers soon after the grafting, a factor retarding growth. To avoid this the leaves, secondary branches, and youngest top internodia were cut from the fan branches still on the trees and set aside for use as graftwood. The treatment made the leaf buds sprout in a few days. Such pretreated graftwood produced excellent results, both in percentage of success and in rapidity of growth (de Graaf, 1941, p. 1194).

GRAFTING IN THE FIELD

A special use of grafting was for increasing the yielding power of producing fields and the grafting on old trees which have lost their bearing surface from neglect or abandonment. Another application of grafting in the field was the gradual improvement of a planting by taking an annual census of all the trees of poor stand or low yield, stumping them, and grafting the suckers with material from a superior mother tree (Cramer, 1924a, p. 76). There were also cases in which it might be desirable to turn a field of a certain kind like common Robusta, into another kind, such as a hybrid better resistant to some adverse climatic condition or a disease or pest. In such a case the branches from all trees were cut except a few at the top to "draw the sap", and a couple of shoots allowed to develop from the base of the tree. One or two of these suckers were then grafted. When a successful graft had been obtained the branches of the old trees and ultimately the whole stem were cut away to increase gradually the sap stream to the graft (Cramer, 1924a, p. 76). When a field had been planted with a less productive kind, grafting the trees with more productive clones might convert it into a better yielding planting. On an estate in the Malang district a 4 year old planting of C. quillou was stumped in 1920 and grafted with graftwood from estate mother trees. The crops for this field totalled 9,045 piculs per bow (78.8 q./ha.) for the period 1921-1930, while another field, planted one year earlier with Robusta seedlings, yielded 85.0 q. piculs per bow (74 q.) in 1921-1930. Both fields began to bear in 1922 and yielded about the same for the first years, a fact that may be interpreted as meaning that the grafts on old trees began production one year earlier and also came into full production one year earlier (Ultee, 1931, p. 47).

A case in which a field was grafted twice was described by Gandrup (1937, p. 419). It was a planting of Quillou 15 Soember Asin, set out in 1910/11. The trees were stumped in 1921/22 and grafted with a number which was subsequently rejected. At the end of 1932 the grafts were stumped again, and in 1933 the shoots from the stock as well as from grafts, were grafted with 6 other recommended C. robusta clones and a new number. In 1937, of the trees grafted, 94 per cent were bear-

ing fruit. In 1934 a small crop was obtained, and after 2 to 2½ years the yield of the grafts had already approached the average for the estate, while in 3 to 3½ years after the grafting, the yield was 30.7 per cent more. Gandrup (1937, p. 420) cited another case in which a field was planted in 1932 with one year old grafts, stumped in the nursery, and yielded 112 per cent more than the average yield of the estate in 1935 and 140 per cent more in 1936, even though the estate had no poor yielders.

A technique by which branch grafts of C. arabica were made on C. robusta trees in the field should be mentioned here. This method had been applied to a limited extent in special cases, viz., for converting C. robusta trees in old C. arabica plantings into C. arabica. Formerly C. robusta was sometimes used on C. arabica estates for supplying, but these isolated trees did not contribute much to the crop. The policy later was to put a new robe on with branch of Abyssinian Arabica so that their product could be mixed with the product of the field. According to the "Vraagbaak" (p. 127) C. robusta plantings just under the C. arabica belt were grafted with Abyssinian Arabica with preliminary success. Sometimes poor trees in old, closed plantings were rejuvenated by stumping at 1½ meters. A sucker was allowed to develop and was grafted with branch wood.

In experiments (see s'Jacob & Hille Ris Lambers, 1938, p. 43) by Bagalso on the Plateau Coffee Plantation (Philippines) it was found that in old Robusta trees the time necessary for the water sprout to emerge varied from 18 to 49 days. The average time was about 4 weeks. The shoots were ready for grafting in 115 to 381 days (Bagalso, 1932, p. 491). The grafts grew rapidly, taking advantage of the reserve food in the old stumped stem. This was not possible for a top graft, since it had to be placed near the soil, thus necessitating the stumping of the old tree at a low level.

When old, abandoned, nearly branchless trees had to be rejuvenated, the field was first cleaned and supplied and the shade put into proper condition. The coffee stems, if bearing shoots, were topped again at 1½ to 2 meters, and then the branches on the old stems reduced, and 5 or 6 shoots allowed to develop at different heights. Each was grafted with branchwood so that the tree was provided with a new "robe". The development of such branch grafts made on shoots on old stems was generally excellent, but special clones were selected for this work. A clone from the Tretes Pangoeng Estate, TP.21, had a good reputation in this respect, and the experiment stations tested various other clones from this point of view. Special crossings were even made for obtaining new mother trees for branch graft clones from these seedlings.

SELECTIVE GRAFTING

The purpose of the gradual grafting of the poorer yielders in a field of about seedlings mentioned above was to increase the total productivity by substituting good, heavy yielding grafts for the poorest yielders. The total yield of the field was increased by this method of "selective grafting" as it is called in contrast with "radical grafting" when all old trees are stumped and grafted (Collhaas, 1941, p. 64). When selective grafting was applied, evidently not all the grafts on suckers of old stumped trees succeeded. Even with stumping alone to rejuvenate the trees, about a tenth did not sprout again (de Stoppelaar, 1939, p. 1327).

The advantages and difficulties of plantings laid out by vegetative multiplication were explained well by Wilson Mayne (1939, p. 186). He emphasized especially the progress resulting from selective field grafting. In a lecture given in 1932 Schweizer (1932, p. 451) had already recommended this system, comparing it with the replacement of the poorer yielders by high grade seedlings, giving the following reasons: 1) Truly superior seedlings were available only in later years. 2) As long as no superior seedlings with uniform higher yields were available, the graft of a well known clone offered a much better chance for replacement of the poor yielding seedling by a better tree. 3) A graft on an old tree produced earlier than a seedling and had a better chance to develop well in a closed planting than a seedling, for which the chances are not too good.

It was found that there was little loss of crop, and the expense was not great. The cost of applying such field grafting was calculated at 2.4 cents per tree in southern Sumatra (Muller, 1932a, p. 512).

For all these reasons the selective grafting in old Robusta coffee fields seemed to appeal more to planters than replacing such old plantings by radical replanting. The latter process involved removal of the old trees, letting the land lie fallow for one year, to rid it of nematodes, and replanting it with superior material. At a meeting of east Java planters in 1934 Gandrup (1934, p. 697) advocated the latter system. In the discussion after his lecture many planters were in favor of gradual rejuvenation by supplying and replacing bad trees with superior seedlings. Some time afterwards a practical planter, de Stoppelaar (1934, p. 811), tried to find an answer to the question of the treatment of various cases of Robusta plantings showing deterioration. Radical replanting was compared with selective rejuvenation and other systems for improving the planting. Snoep (1939a, p. 810) came to the conclusion that in all Robusta plantings selective grafting was necessary and

practical, preferably with branch grafts. For radical grafting top grafts were recommended. Re-planting was also possible, although plans should have been made for several years in advance in order to have sufficient planting and grafting material on hand.

Some years later a number of cases of radical and selective grafting were studied by Coolhaas (loc. cit), and the annual yields were reported from the different grafts. From these data it could be concluded that when healthy illegitimate seedlings were grafted with good clones there was first a decrease of the crop for 4 or 5 years, the period in which many grafts are still too young to give a good crop, but afterwards the yield reached a considerably higher level that was maintained for several years. By comparing the fluctuations of annual individual tree yields of 400 trees over a period of 7 years Coolhaas (1941, p. 70) reached the conclusion that when the trees which gave a low yield, which was less than half the tree average of the field for the year, for two or three consecutive years or those belonging to the poor production classes were cut, the objective of eliminating the poorest trees was attained. If it were assumed that over 6 year period the poorest yielders, as determined by two years' figures, were to be grafted with superior clones, it could be calculated that there would be first a period of 3 years in which the yield would decline about 11 or 12 per cent. Then there would be a regular annual increase of the yield amounting to about 36 per cent for the following years. Thus the loss in the first period would not only be compensated, but there would also be a considerably higher productivity resulting from selective field grafting.

The practice of grafting on old trees without value after stumping them was further described by de Stoppelaar (1939, p. 1326). The grafts were made with branchwood. The ultimate percentage of success was 65. The failures and old stumps unfit for grafting could be replaced by grafts as supplies. The percentage of successes were increased by using clones which were readily adaptable to the stocks on which they were grafted. The best results were obtained with BP.42 (85 per cent), BP.39 (80 per cent), and SA.34 (80 per cent). The author also gave particulars about pruning his grafts.

MULTIPLICATIONS BY CUTTINGS

As another method of vegetative multiplication the propagation of coffee by cuttings has been tried over a long time. When *Liberica* had just been introduced there was a great demand for planting material. In those days the berries of the promising new species were sold at f 0.5 (Guilders) per two-seeded berry at public auction (Wigman, 1888, p. 8). To help the planters secure the keenly desired material as quickly as possible, experiments in multiplying the recently introduced trees by cuttings were made in the Cultuurtuin with some success. Very young green pieces of wood with short internodes gave the best results. Over 2000 cuttings were put in the nursery, and while very few died, only a few struck roots. After the rains set in the rooted ones could be removed so that at the end of the experiment there were still 2,000 unrooted. Of the total, 332 plants had been set out, and there were 25 rooted cuttings (Verslag, 1877, p. 27). The following method was used: A small pot was put upside down in a large pot. The small pot rested on sand, and the space between the two pots was filled with sand. The cuttings that had been made from shoots were then put in the sand and well watered. The whole large pot was then buried to the rim in nursery soil and covered with a glass jar (van Romburgh and Wigman, 1896, p. 516). That the propagation of *C. arabica* from cuttings was an old practice in the Netherlands Indies was clear from an account by Holle (1879, p. 3), who stated that in 1852 he saw used, the application of auxins, and the influence of ringing in connection with cuttings of *Arabica*. The cuttings were placed in propagating cases consisting of structures with low brick walls covered by a glass frame. High humidity, favorable lighting, and a temperature as low as possible were found to be essential factors. These were obtained by placing of cheese cloth kept wet during the whole day on the glass and building a roofing of matted bamboo over the propagating cases, thus keeping out 70 per cent of the sunlight. The objective was to let in sufficient light for the growth of the material but at the same time to avoid a rise of the temperature in the inside of the cases. Thus the temperature was kept, at 27° to 28° C. in the middle of the day, and at 20° to 22° C. at six in the morning. The cheese cloth was kept wet by letting water drip on it from a bamboo conduit. Inside the cases was a layer of sand 20 centimeters deep on a layer of ten centimeters of gravel.

The most suitable tree material of *Robusta* consisted of pieces of young stem suckers, and the tops gave the best results. These tops were pieces 20 to 30 cm. in length, with 1 or 2 nodes in addition to the top, and 2 or 3 leaves of which half was cut so that each leaf had a surface of about 50 sq. cm. Care had to be exercised to keep from damaging the leaves, since leafless cuttings soon died. The presence of the leaves on cuttings and the correct lighting were most important elements in success. The planting distance inside the cases was 8 cm. on the triangle, giving 180 cuttings per sq. m. If suitable *Robusta* material was used, 77 per cent of the cuttings were rooted after 3 months, and another 20 per cent were still alive. Cuttings from the young parts of a shoot, a pri-

mary branch or a "fan" branch, always gave better percentages than those made from older wood. Cuttings from the top sometimes showed a better percentage, sometimes no difference with the piece of wood below it, but root formation started as a rule earlier with top cuttings. The place of the basal cut above or just under a node had no influence.

The roots started to develop $\frac{1}{2}$ to 2 months after the cuttings were set out. Most cuttings were rooted in 4 months and 5 to 6 months after, the cuttings could be transplanted. With orthotropic cuttings the roots went straight down as a rule; with cuttings from branches the roots were more horizontal. The use of auxins sometimes had an unfavorable influence and did not produce material advantages. Robusta Bgn.124.01 struck roots more quickly than Bgn.300 while Congusta SA.36 rooted earlier than SA.24. If desired, the cuttings could be grafted just before putting them out in the cases, and even then over half were successful. A brief summary of the experiments with some practical hints were given by Roelofsen (1939d, p. 944, discussion p. 1002) in a lecture at a planters' meeting in which he stressed the advantage of cuttings in comparison with grafts. The latter required year old seedlings and it took about 6 months to secure plantable grafts. The cost for a multiplication frame sufficient for raising 2,500 cuttings was about f 45. Watering and other upkeep required about an hour a day.

The earlier study by Roelofsen and Coolhaas was later completed by Roelofsen (1940, p. 112, table p. 113) with data confirming the foregoing conclusions. When cutting the leaves was reduced, a measure which improved the results to some extent, it was found to be unnecessary to increase the planting distance. Large differences in percentage of success were found for the various Robusta clones, and the following figures relate to the percentages of rooted cuttings on the total number put out: SA.34 gave 90 per cent; SA.56 gave 73; SA.13 gave 42; BP.42 gave 35; SA.109 gave 76; SA.158 gave 65 and BP.39 gave 75.

The results for Robusta coffee described for Java can be supplemented with a few practical hints on the technique applied to the propagation of cuttings of C. arabica in the experiment station at Lyamungu, Moshi, Tanganyika (Fernie, 1940). The suggestions are based on experiments in Lyamungu at 1,300 m. on the southern slope of Kilimanjaro. It was found that as starting material, shoots from main stems should be used. They ought to be 10 to 15 cm. long and with 2 or 3 internodes. As soon as plants from cuttings were obtained, it was suggested they should be planted in a clone nursery for intensive multiplication, say 20 plants per clone. Planting distance was best at 4 or 5 ft. square, allowing several stems per tree. After 18 to 24 months all primary branches were removed. The stems were bent and fixed in a horizontal position. The serial buds near the nodes developed new shoots in abundance. These new shoots could then be cut, and only three shoots were kept and bent in their turn. High shade was recommended. Every 4 to 6 weeks suitable suckers were taken off. They were selected for health, with normal leaves, short internodes, a round stem, and 10 to 20 cm. in length.

For the rooting cases in Lyamungu the following dimensions were given: length 1 m., width 30 cm., height of back wall 90 cm., height of front wall 75 cm., thickness of walls, 12 cm. Walls were made of brick. In the center of the walls there were wooden beams 5 cm. square on which the glass frames were laid. A layer of gravel 45-60 cm. deep on the bottom was for drainage. For the growing medium coarse sand mixed with peat (sphagnum), 1:1, was suitable. For disinfection, the walls were painted with a solution of Cheshunt Compound, and the cuttings soaked in this solution for some time. Before the cuttings were put out the basal cut was made through or near a node as a clean cut, and the lower leaves and eventual twigs removed. The other leaves were cut, small ones to $\frac{2}{3}$, bigger ones to $\frac{1}{2}$ their size. Cuttings were inserted to a depth of 3 to 5 cm. The temperature was kept at 20° to 23° C. by dripping water on a piece of cloth. The moisture content inside was kept at 90 per cent by using a vaporiser once or twice a day and also when the frames were opened. The sunlight was reduced by a roofing.

Callus formation began after 3 weeks. After 6 months it was found that $\frac{3}{4}$ of the cuttings had struck roots. It was better not to wait for the others, although some more would still strike roots. When the roots were $2\frac{1}{2}$ to 5 cm. the plants were transplanted to baskets, put back into the cases and kept there 3 to 4 more weeks until they had recovered from transplanting. They were then hardened outside in the shade for 3 to 4 months, and then could be put out in the nursery.

In the review by Feildon G. St. Clair (1940) a very complete description of the work on propagation of cuttings was given. Even the oldest experiment which was with C. liberica in the Cultuurtuin in 1877, was mentioned (p. 46). It described the valuable work done by the Lyamungu Coffee Research Station and at the Scott Agricultural Laboratories in Kenya and mentioned (p. 43) that in March 1938 what is believed to be the first coffee field experiment in which material consisted entirely of rooted cuttings was laid out at Lyamungu. It will be extremely interesting to follow these field experiments further. Laboratory work will show the extent of practicality of the new method of propagation and the extent to which it can be included in the routine work of estates.

The last word has not yet been said about the raising of planting material from cuttings. From the experiments by the British and by Roelofson and Coolhaas it may be concluded that the method promises to open up fruitful new ways for improvement with great possibilities. However, at present, it must be considered to be still in the experimental stage. The yields and practical value of plots of adult trees established by this method must be known before it can be introduced into the regular estate technique on a large scale.

CHAPTER 12
GROWING THE CROP

SOILS

In general it may be said that coffee is an exacting crop. For long production, it requires good, well drained soil with a good quantity of humus and permeable enough to allow a good development of the root system. In the days of the government plantings in Indonesia and in the initial period of the private planting industry there was still plenty of forest land for laying out new coffee fields in Java. This is no longer true, although many estates still have some reserve land. On an earlier page, the importance of keeping the humus on the land available for the coffee has been mentioned and attention has also been given to measure for protecting it from erosion.

Coffee is planted on a wide variety of soils, ranging from heavy clays in central Java to very loose volcanic ash soils on the Keloed mountain. A good early description of the various coffee soils from a practical point of view was given by Kramers (1900, p. 37). A later and more complete description of coffee soils in the coffee district around Malang was published by Senstius (1916). The soils of the recent volcanoes Keloed and Someros are lighter than those of the southern mountains and Kawi, for which the decomposition had progressed further, a circumstance indicated by the sand fractions consisting of iron concretions in the latter.

Coffee does especially well on rich volcanic soils of recent formation such as those on the slopes of the active volcanoes Semeros, Keloed, Tengger, and Raeng. According to White (1921, p. 284), the ashes ejected from the Keloed are the richest volcanic ashes in Java. Coffee is also grown in the southern mountains near Malang on older lateritic soils. In east Java an exceptional case is found on an estate with a patch of a couple of hectares of peaty soil where coffee was grown successfully many years by increasing the free board through a thorough draining system. Here the root system of the coffee spread mainly in the topsoil, about a half a foot deep (Snoep, 1932d, p. 690). The success of this planting did not continue, as Snoep had predicted (van der Veen, 1938b, p. 345).

A survey of the soils from estates in the area covered by the Malang Research Institute was published by Snoep (1936a, p. 255), who attempted to summarize the values found with 238 soil analyses made by Vogeler's method. Snoep stated that it was useless to try to find a relationship between the properties of the soil and the yield of the coffee plantings because the latter depended on climatic factors. The review of the data aimed only at giving some ideas about the weight and distribution of the values found for the soil factors. The various soils in the area covered by the Besuki Research Institute were described in an article on "Bodentypen" by R. van der Veen (1934).

In Central Java, where the planting industry is generally older and the soils have been under cultivation for a longer time, a good deal of attention must be paid to their condition. By application of green manures, mulching, terracing, and occasionally by application of artificial and stable manure, new plantations can still be established there. Even when the land has already been in coffee for several decades, they can be replanted. On recent volcanic soils such as the Idjen highlands and neighboring mountain slopes, both *C. arabica* and *C. robusta* thrive, and *C. robusta* also gives high yields on the rich, deep younger lateritic soils of the Kawi. The liberoids grow well on these soils, but they can also be grown successfully on more compact clay soils. In Sumatra some recent volcanoes as Tengganoes, Korintji, Dempo and Kba, and Merapi, all have highly productive coffee estates on their slopes.

Snoep (1941, p. 182) studied the influence of soil quality on coffee in east Java. The nitrogen supply available was probably of major importance in these soils, which were comparatively rich from a chemical viewpoint. The differences in quality of coffee must often be attributed to the structure of the soil and the nitrogen supply in connection with it. There are, however, other factors as well which have an effect on its growth.

Keuchenius published some figures (1937, p. 307) on the important role played by lime in the soils of west Sumatra along the coast. There was a clear relation between the lime content of the soil and coffee yields, especially of the top soil. This relationship is understandable inasmuch as coffee develops most of its roots in the top layers.

A general survey of the soils of Indonesia may be found in the work by Mohr published in 1933-1938. The first volume, comprising Parts I and 2, both dated 1933, describes the petrographic material from which soils originate, the factors influencing the soil forming processes, and the details of these processes. The second volume comprises four parts, published in 1934, 1935, 1937, and 1938 respectively. In the last volume there are numerous instances of coffee planted on specific soils, but the notes are not put in a form that permits summarization here.

RAINFALL AND WIND

As far as climate is concerned, it may be said that coffee requires a fair quantity of rain.

An annual rainfall of 1,500 - 2,500 mm. may be considered favorable, although Arabica may thrive on no more than 1,000 mm. in the higher altitudes. In Java and nearby islands the climate is seldom too dry for coffee growing, but in east Java very dry years may do harm by causing the loss of young plants in new plantings, spoiling the crop, and permitting increased attacks by pests such as scale insects.

Since coffee is a fruit grown for seed, its success or failure depends largely on the weather conditions during the flowering. If a shower hits the blossoms on the day the flowers are open, a complete crop failure may result.

A wet year is generally followed by a crop less than the average. At least this seems to be an old observation in the case of C. arabica (Burck, 1896, p. 7). On the other hand, severe drought may also do damage. In 1926 many estates in east Java suffered from excessive drought. During such a drought the desiccated flowers remained attached to the setting fruits. They harbored several kinds of insects, numbers of lice, scales, and a little caterpillar, which did so much harm that in one case where these dry flowers were not removed in some fields, no crop remained on the trees.

The crop was saved wherever they were removed (Ultee, 1926, p. 168). Diseases and pests may also reduce the crop in unfavorable years when proper measures for control are neglected. The effect is that the same area may yield highly variable crops in consecutive years especially when planted to the very sensitive C. arabica, although this is less true with C. robusta and C. liberica and least of all with most hybrids. The latter show a strong resistance to unfavorable weather conditions, diseases, and pests.

In some parts of southern Sumatra the rainfall is too heavy for successful production of standard coffees, so that special kinds are chosen. The young, still open trees of usual types may give good crops, but when they get older they form too many leaves and yield too few fruits. A marked dry season has a beneficial effect in that it provokes substantial blossoming. In east Java a dry period of several months often occurs. When the rains break through at the end of this period, at first in occasional showers alternating with short dry intervals, the weather is ideal for flowerings, and the trees will flower profusely. In the good coffee districts in east Java, on the Kelod and Semeroe mountains, it is practically certain that the months between June and September will show an average of less than 10 rainy days, while the months with an average of 20 or more dry days are very rare on the slopes of Kaba and Dempo (south Sumatra). The effect of this continuous rainfall is that the crop is continuous, although there is a cropping season of about 5 months where about 80 per cent of the crop is produced. In east Java the annual crops are usually concentrated in 6 months, and the cropping season of successive years are separated by equal month periods in which no crop ripens (Hoedt, 1929, p. 893).

On the other hand, excessively dry conditions may also do damage. Schweizer (1935b, p. 170) studied the influence of an intensive drought on the physiological conditions of Robusta coffee and tried to find the factors determining drought resistance. It was observed (de Haan, 1923, p. 20) that in the mountainous districts where many coffee estates were located showers could be very local, and the ground could be absolutely dry 100 m. from a spot where a heavy shower fell. For this reason station rain gauges were set only 500 m. apart at Bangelan. They often gave very different data at the beginning of the rains when one spot might catch a local shower that another part of the planting missed (Cramer 1916c, p. 406). This circumstance might make the record of effect of a heavy shower uncertain as far as the whole of the estate is concerned.

It is known that a marked dry season is also favorable for bringing in and curing the crop. During drought, roads are in better condition, and part of the drying can be done on drying floors in the sun. Further notes on the special requirements of the various species of coffee in connection with rainfall have been included in the sections on these species.

Coffee in Indonesia was long known as sensitive to wind. Especially the hot, dry winds in the dry season did a great deal of harm. If the trees were definitely exposed to such winds, they needed protection by a wind breaks, for which shade trees were suitable. A well kept shade over the plantings also formed a protection from wind. Huitema (1935, p. 204) gave a list of plants especially useful for giving protection from the wind. The bushy ones, mostly green manurers like Crotalaria anagyroides and Tephrosia sp., were suitable in young plantings. Leucaena glauca could be kept as a bush by repeated cutting back. The trees suitable for planting as windbreaks included several Leguminosae, and Inga laurina and Grevillea robusta had a place on this list. Rows of windbreak-trees were planted at gaps of 20 m. or more from one another (Sladdon, 1931, p. 317).

Coffee does not stand frosts which may occur in higher altitudes, for example on the estates on the Idjen plain. In those places it is customary to establish a dense shade and not to plant the young coffee until this protective covering is two years old. Under the cover of the shade trees the coffee is protected from frost damage.

ALTITUDE ABOVE SEA LEVEL

With the presently available species, coffee can be grown in Indonesia from sea level up to 2,000 m. The various species have different requirements in this connection. In the old days of Arabica it was grown both in the mountains and near the sea coast ("beach gardens") in the coastal plains such as those near Batavia (Kalff, 1927, p. 142). However, when leaf disease invaded Java, it drove C. arabica back to the higher regions. It is convenient to distinguish three belts: a lower one, up to 300-400 m. above sea level; a middle belt from 300 m. to 400 m. up to about 800-1,000 m.; and a high belt from about 800 m. to 2,000 m. In southern Sumatra the upper limits of these belts are somewhat higher. Robusta does very well there as high as 1,000 m. Roughly the various species find their optimum altitudes as follows: C. liberica and allied species in the lower belt, C. robusta and allied species in the middle, and C. arabica and its varieties in the high. These limits are not absolute.

C. liberica was successful at one time in the middle belt as well, although its development there was slower. The same can be said of C. excelsa, which still grew, however, slowly, in the high belt where C. robusta did not thrive. In the low belt Robusta might be grown on a commercial scale, although it was likely to be somewhat more subject to diseases and pests than at an altitude of 400 m. to 700 m. where it seemed more at home. In southern Sumatra the estate coffee industry of Robusta was localized mainly in regions on the slopes of volcanoes at altitudes of 500-1,300 m., in the Lampong district at 300-400 m. The native plantings were situated mainly in the higher parts of the same regions. In 1914 these plantings produced about one per cent of the total exports of coffee from Indonesia. In 1928 it was roughly 47,000 tons or about 37 per cent of the total exports (Hoedt, 1930, p. 59), which indicates their relative success.

It is apparent that the altitude at which coffee grows, influences to a certain extent the quality of the market product. The plantings of Robusta in the lower plains of Indonesia only a few hundred feet above sea level, yielded a smaller bean than those in the middle belt. At higher elevations C. arabica gave larger beans, although at very high altitude the bean seemed to become smaller again. The altitude at which arabian coffee was produced also influenced the taste. The higher the altitude, the finer the flavor. This high altitude influences the flavor even more than hereditary factors. A curious test of these differences can be cited (McClelland 1924, p. 6). Various kinds of C. arabica produced in Puerto Rico from the local variety and several introduced kinds (Java, Jamaica Blue Mountain, Guadeloupe, etc.) were submitted to taste test by New York experts. They had no trouble in picking out the genuine "Mocca" and Java drawn with the samples. Of the Puerto Rican coffees those grown at highest altitudes were, almost without exception, the best. The consensus of opinion was that the coffees introduced from other countries and grown in Puerto Rico retained little, if any, of the quality of the original.

As explained in the chapter on Hemileia, the leaf rust disease is a limiting factor as to elevations for growing coffee. The equilibrium between Hemileia and coffee is threatened outside of the most favorable belt, and it is maintained in favor of the coffee only at the optimum altitude for the various species. A curious proof of the fact that when Hemileia is absent, C. arabica can be grown even at sea level, comes from Surinam, a country completely free from the disease. There some "Surinam coffee" as C. arabica is called there, is still produced in the polderland near the coast. C. arabica was also formerly produced in the Amazon basin at about sea level, but toward the middle of the last century the cultivation was neglected, and by 1870 it could be considered wholly abandoned (Le Cointe, 1922, T. 2, p. 195). Apparently this was due entirely to economic reasons, not to technical difficulties. Before the leaf disease appeared, Ceylon also had its coffee plantings in the low country. The plant grew vigorously as well at an elevation of 1500 ft. or more (Simmonds 1864, p. 46).

The various hybrids, with their great resistance to Hemileia and other diseases and adverse conditions, are less exacting and have a less marked distribution in connection with the altitude above sea level.

CHAPTER 13
THE SHADE PROBLEM

GENERAL

In Indonesia coffee is nearly always grown under shade of other trees, preferably Leguminosae. Practical experience has shown that, generally speaking, shade is beneficial and under certain circumstances indispensable for the growth and normal fruiting of coffee trees. While in some South and Central American countries shade trees are used, this is not the case in the great coffee region of Brazil. Lalière (1909, p. 110) has noted that shade trees were unknown in the "fazendas" of Sao Paulo and would be of no use there. In Colombia all coffee estates had used shade trees. The most common shade trees were reported to be Erythrina umbrosa and E. edulis, Inga vera, I. sapida, I. edulis, and a few other species (Sladden 1931, p. 315). In Guatemala shade was sometimes planted, for which purpose an indigenous, fast-growing tree was used (Morren 1899, p. 60).

In Africa opinion seems to have been divided as to the advantages of shade. The planting of shade trees is general in Madagascar. Albizzia stipulata and A. falcata have been reported as sometimes used, but they suffer from wind damage. A. leboeck, "bois noir", is more resistant and seems to have given good firewood, but it grows slowly and is leafless for several months. Another indigenous species, A. fastigata, was reported as sometimes used by the native, but its growth was extremely slow (Ledreux, 1933, p. 73). As early as 1908 the use of shade trees was widespread in the Belgian Congo, although it was not general. Species of Albizzia in particular were recommended (Manuel pratique, 1908, p. 20). Zimmermann (1903, p. 383) advised the use of shade trees for improving the condition of the coffee plantings in German East Africa. In the higher plantations of Arabian coffee in Kenya and the Kivu region (Hille Ris Lambers, 1939a, p. 1802, and on the C. arabica estates in Abyssinia shade is sometimes planted, but it is not at all general. Van der Veen (1939, p. 821) attributed the lack of shade on coffee estates in the Congo to the acidity of the soil. In the northern and eastern sectors where the soil was less acid, and there were also frequently estates without shade. However, other measures had to be taken to compensate for lack of shade.

In the Kona district of Hawaii no shade whatsoever was used (Ripperton, Goto, & Pahan, 1935, p. 37, note picture, p. 7). In southern India it seems to have been necessary to grow coffee under shade (Anstead 1915, 3p.). In the old days, when coffee cultivation was still flourishing in Ceylon, the planting of shade trees was discontinued about 1840, since they were considered harmful to the coffee shrub (van Spall 1861, p. 99). Coffee is no longer produced in the Island of Ceylon.

In Indonesia, coffee can be grown without shade only under exceptional conditions. In the lower plains, where C. liberica once found its optimum conditions, fields could be kept without shade (Cramer 1913, plate 2, p. 10) and still produce very well. In the middle belt repeated attempts have been made to grow coffee without shade, generally unsuccessful in the long run, although a few estates succeeded in establishing and keeping fields of Robusta without shade for some time by certain treatments of the soil. On Arabica estates at higher altitudes a good deal of care needed to be given to the shade trees. Planters in these regions often say that the shade there requires more attention than the coffee, but that only when the shade is well cared for will the coffee yield well.

The planting of shade trees has long been generally unpopular among the native coffee producers except in the native C. arabica plantings in Bali and in the Ranau district. In Sumatra most coffee was planted without shade. When shade was used, dadap was preferred, and lantoro was unpopular. The objection to it was that the tree produced large quantities of seed which produced volunteers in the fields, thus necessitating extra weeding. The pruning of lantoro also demanded more skill (Huitema 1935, p. 147).

In the wild state practically all coffee species grow in the shade of the jungle. This is true for C. liberica, C. robusta, and C. arabica insofar as data are available in the descriptions of these species. When C. arabica was first adopted as a tropical crop, the need for shading it was soon felt. In C. arabica, shade trees seem to have been used for coffee as early as the first part of the eighteenth century (van Stein Callenfels 1916, p. 36). According to an old description, coffee in Arabia was cultivated on lower ground surrounded by large trees for shade (Simmonds 1864, p. 43).

Although the name "shade trees" might suggest that their beneficial action consists in protecting the coffee from direct sunlight, the relationship between them and the coffee under them is much more complicated. Ottolander (1903-1904, p. 673) reviewed the shade problem in a lecture at a Planters' Conference at Malang in October 1903. His ideas still seem fresh and have not been superseded by any more recent study on the subject as a whole. As a matter of fact, the later literature is all on details, not on the problem as a whole. A second and more extensive article by Ottolander (1905), "Gegevens betreffende het schaduvraagstuk", a lecture to the Eighth Coffee Conference at Soerabaja in 1905, was reprinted in the Bergcultures. It contains the replies to an inquiry among planters

about the shade problem, with many details about the various species used and tried.

In his first lecture Ottolander said that if the only function of the shade trees was to give some shade to the coffee, it would be easy enough to find some tree with a nice canopy in the neighboring jungle and to plant it among the coffee trees. Experience showed, however, that coffee did not grow under every kind of tree. For instance, it disliked strongly Cassia florida and thrived in the presence of dadap a species of Erythrina. The problem should have been studied by a botanist, although it never was. However, Ottolander's rich experience, as revealed in his lecture, still serves as a basis for choosing shade trees. He noted that even in a climate with a cloudy sky, coffee still required shade in a very slight degree to produce healthy blossoms and fruit. The reduction of the light by the shade helped to protect the soil from direct sunlight; and the leaves scattered on the soil, from the shade trees together with the coffee leaves, formed a mulch which became humus and kept the soil open. Ottolander said (loc. cit., p. 678) "there is no cheaper and more practical soil treatment, no better and more efficient manuring than this". He compared the action by which the shade trees pump the nutriment up from the subsoil and strew it in their leaves over the top layer, with the fertilizing action of chemically rich irrigation waters, spreading material rich in plant food that has been washed away from the mountain slopes, over the rice fields.

Schweiser (1941, p. 704) ascertained by chemical studies, what shade trees gave to the soil by dropping their leaves and what was used and fixed in them by their growth. Keuchenius explained the same process for Albizzia. Ottolander was a firm believer in shade for coffee and quoted from an old description of coffee dating from the beginning of the eighteenth century, "This tree loves a shaded soil". It was found (Snoep 1932b, p. 1413) that shade increased the moisture content of the upper 5 cm. layers of the soil, but at 15 cm. the unplanted soil showed a higher moisture content than the shaded. Ottolander reported the temperature observations made at his request by Couvreur, who found that with due precautions against direct effects of sunshine, in shaded fields the temperature averaged 7° C. lower during the day than in the open field. During the night under shade it was 3° C. higher. On the Idjen plains in Java, where the altitude and a dry climate often cause night frosts very harmful to coffee, shade is essential and is generally well established before the coffee plants are put out.

A comparable situation exists at the higher altitudes in some regions of Belgian Congo where C. arabica is planted. Here this species sometimes shows "black tip" ("brulure"), a characteristic disease in high altitudes above 2,000 m. and in medium altitudes in valleys at 1,650 to 1,750 m. It is attributed (Jurion, 1936, p. 9) to sudden changes in temperature after sunrise which may amount to 26° in two hours. In places where black tip occurs, shade seems to have been the sole remedy. In the Experiment Station at Mulungu, in the Kivu, experiments were further conducted (INEAC. 1939, p. 179) with shade trees over coffee to study the effect from a general point of view, with results still not fully reported.

It was early agreed that the presence of the shade trees over the coffee trees helped to shade the soil. This was probably an important point. From a few small scale experiments (Gandrup 1935a, p. 182) it was concluded that coffee probably could do with only a small amount of shade if the soil was covered.

We have already noted (Huitema 1935, p. 182) that in the native coffee planting industry the shade problem had received little attention. As coffee land became scarcer, the native planter was forced to take steps to prolong the productive life of the coffee trees. One of the measures has been a rational application of shade. Huitema provided an excellent introduction to the problem, summing up the advantages and risks and difficulties of interplanting shade trees between coffee trees and reviewing the main species with their pros and cons. An interesting table by Keuchenius (1927, p. 465) gave the percentages of the root system in the successive layers of fairly permeable soil. In the top layer at 0.50 cm. there was found 68 per cent of the root system of Derris microphylla, 55 per cent of Albizzia falcata, 53 of dadap, and 43 of lawtoro. The lawtoro seedlings, about 10 months old, had developed roots as deep as 4.5 m. Photographs of the principal kinds and excellent notes on their habits may be found in Holland (1931, p. 197).

ERYTHRINA

In the same review the shade trees that were popular at the time were enumerated. The list was headed by the dadap serep, Erythrina lithosperma var. inermis, and a Papilionaceae which was preferred for at least a century. Indeed, it was the only shade tree at one time. Even the old Dutch East Indies Company issued a directive in 1789 to plant it between the coffee trees, and it has since always topped the list. It would be an ideal shade tree if it did not have one weak point. At the end of the nineteenth century it proved to be very susceptible to a bacterial disease of the roots, a cicada, a scale, a caterpillar, and a beetle. Several serious diseases and pests of Erythrina have been enumerated by Huitema (p. 187). They have been difficult to fight. That the

dadap often showed less vigor, resistance to disease, and vitality was attributed by ten Hones (1908, p. 667) to lack of care. He recommended careful choice of the trees from which the cuttings were made, meticulous attention to the planting from these cuttings, and tending and pruning of the young trees. Others planned multiplication on continuous vegetative multiplication. The thornless variety had been multiplied by cuttings for many years, and the increasing number of enemies was ascribed to this circumstance. The wild form with thorns was known to be much more vigorous. Planters then tried to raise seedlings from the smooth variety. They were generally thorny and did not thrive as well as the common dadap grown from cuttings (Kramer 1900, p. 75). The same was true of cuttings from these seedlings.

Other kinds of *Erythrina* were also tried. For example *E. crassifolia* Kds. "known as dadap solo", was thought by some (van Helten 1918, p. 74) to be a hybrid of *E. lithosperma* var. *inermis* with *E. variegata* var. *orientalis*. It met with favor in some quarters. For instance, it was used in the Cultuurtuin at Bogor. One disadvantage to it has been that in dryer, higher climates the crown became too compact. Several foreign *Erythrina*s have also been introduced. While some seemed promising, they disappeared from the collections of the Cultuurtuin at Bogor inasmuch as they did not seem to thrive well in the moist climate.

Erythrina micropteryx (= *E. poeppingiana*) seems to have been especially noted for its heavy droppings of leaves which helped to maintain the humus content of the soil at a fair level (Anonymous 1939, p. 1701). This kind of dadap was introduced by the Cultuurtuin in 1912 from Venezuela under the name of "Bocare anauco" together with "Bocare pecnio", presumed to be *E. velutina*. A few plants were obtained from the introduced seed and planted in a test plot with other kinds of dadap, mainly indigenous species. Although all the trees in the plot suffered from abnormal leaf fall due to the action of the "dadap fly", *Typhlocybe erythrinae*, and top borers as well, the newcomer was of much interest. When 2½ years old, trees measured 6 to 8 m. in height. The stem and branches were thorny, with smaller twigs thornless (van Hall & van Helten, 1915). The species is still present in the collections of the Cultuurtuin. It can be multiplied by cuttings, but only with some difficulty. Marcotting might be easier. *E. micropteryx* was also tried on the Idjen plain. It got off to a slow start, but once established, the growth was vigorous. The leaves developed well and suffered very little from pests (Schweizer 1933a, p. 74).

Several species of *Erythrina* more or less suitable as shade trees for coffee in east Africa have been found indigenous there (Thomas, 1940). They had the disadvantage of dropping their leaves in the dry season, but otherwise at least one of them, *E. excelsa*, made a good show. As far as is known they have not been introduced into Indonesia.

Java planters introduced from the nearby Soembawa islands, varieties of the dadap serop, thinking that they were more vigorous and disease resistant, but ultimately they too were attacked. At present dadap serop is still used because of its excellent properties. It is easy to multiply by cuttings, shows a quick growth, provides a leafy canopy, is easy to prune and control so that the amount of shade can be well regulated, and drops a great quantity of leaves to form an excellent layer of debris on the soil. This old friend of the coffee planter, of which Raffles, speaking in 1819, said, "where dadap thrives" is still considered of value for estates in a dry climate, and may reduce expenses for upkeep. However, Snoop (1932b, p. 1453) considered that it would probably be necessary to rejuvenate the trees periodically. In east Java the use of dadap was markedly increased according to Colesse (1933, p. 451) who gave useful hints on how to plant and treat the trees.

If we consider the dadap as a temporary tree which could be replaced by younger ones when the older ones have attacked too severely by diseases and pests, it can certainly be useful. However, it does not give the solution of which Ottolander dreamed when he said that dadap is the shade tree par excellence and that therefore it should not be left to itself but that attempts should be made to improve it. He thought that it could again become a good shade tree when it was planted less densely and mixed with other shade trees so that the effects of enemies might be counteracted. It is curious to note that this policy advocated by Ottolander in 1903 has become more popular in recent years.

ALBIZZIA

Another old timer among the shade trees is the "sengon laet", or *Albizzia*, which was often used for replacing dadap when the latter began to succumb to disease and pests. Ottolander was enthusiastic about it for protecting deteriorating coffee fields from further decline and improving them. It was curious to note the favorable influence of young *Albizzia* on coffee. However, the tree also has its disadvantages. It was very susceptible to breaking by winds and to the attack of a beetle which damaged the bark of old trees. As long as there were only a few *Albizzia* trees planted here and there between dadap, the pest was not noticed, but when hundreds of hectares of *Albizzia* were planted in a soil block the pest gained the upper hand, and all older trees were attacked. The

kind generally planted in Indonesia was A. moluccana (A. falacata Backer). Ottolander recommended it for every locality where dadap declined, even if the Albissia was attacked. The attacked trees could be replaced continually by young ones. Ottolander considered it a great soil improver, but he thought the old trees less suitable with their excessively heavy canopies.

Good results from the planting of Albissia falacata were reported from west Sumatra by Keuchenius (1938, p. 270), but it was kept there only two years. He found (p. 311) that the tree extracted the Ca-ion from the soil and gave it back to the topsoil in its leaves. Thereby it soon enriched the topsoil with lime which it took from the subsoil where it was out of reach of the coffee roots. The Albissia roots went deeper than those of coffee. De Vogel (1895) long before also mentioned Albissia and noted that it was formerly frequently planted in places where dadap would no longer grow but that it was abandoned because of beetle and wind damage.

A plot of 0.4 ha. in the shade tree test at Bangelan was planted toward the end of 1903. It suffered from windbreak from the first, and in 1905 several trees were lost by borer attacks (Jaarverslag 1905, p. 158). A year later only 11 living trees remained (Jaarverslag 1906, p. 346). The experiences of Celosse with this tree were similar. He said that old Albissia trees in a coffee field were a curse and young ones a blessing. Albissia kept down the noxious grasses, could easily be controlled, and gave a good quantity of leaves. Celosse praised especially its salubrious influences on nematode-infected fields. With the aid of Albissia he was able to re-establish a flourishing coffee planting on a nematode-infested soil. In the discussion after Celosse's lecture similar experience were cited by other planters. In the debate on experiments on measures against nematodes, the plantings of Albissia were mentioned. Pfaltzer (1937a, p. 1368) thought that while this could do no harm, it could not be assumed that Albissia drove away nematodes, since the pest also attacked Albissia roots.

Albissia was planted either as basket plants or as stumps. On some estates only thick stumps were successful, while on others thin stumps gave good results (Notulen, 1934, p. 1021).

Young Albissia moluccana seedlings often suffer in the nursery from a fungus disease which Ottolander observed as early as 1905. Therefore, Celosse (1937, p. 322) recommended establishment of small nurseries in several places on an estate. If some were lost by the disease, one or two others might escape it. He further advised that Albissia seed be mixed with lantoro seed, reporting that he obtained good Albissia plants by this device. The disease in question was found to be caused by a fungus, Ceratophorum albissiae, and it was successfully kept under control by spraying with Bordeaux mixture (de Haan 1938, p. 303). In addition to A. moluccana, Ottolander mentioned A. stipulata or sengon. When planted alone this tree seemed unsuitable, since the growth was too slow, but this species was comparatively free from disease. A third species, A. montana, a kind growing at higher altitudes, was also reported. On Ottolander's estate it was used to improve the soil where only lalang grew and where A. moluccana and dadap would not grow. A. montana grows on the poorest soils, old grass fields, pure sand, and gravel and thus can prepare the land for better trees.

A little known species of Albissia used as a shade tree in Indonesia has been A. sumatrana from the west coast of Sumatra. It is characterized by very small seed. The tree spreads well and provides a very regular light shade. In west Java it gave better results than A. falacata at an altitude of 1,200-1,400 m. on badly washed slopes. In some places it was found more resistant to borers and wind. It seems to have been planted best as basket plants (Prillwitz 1931, p. 129).

Another species of Albissia which could appear to deserve attention (Chevalier and Trochain 1939, p. 430) is A. malaccarpa, introduced by Fritz in 1933 from El Salvador to France. From the Jardin Colonial in Nogent sur Marne it was distributed to the French colonies. In Cameroun, where it was called as "Pisquin du Salvador", it gave excellent results. Its habits resembled those of lantoro, but the leaf stalk or rachis was covered by a brown pubescence.

LEUCAENA GLAUCA

In 1901 when the Bangelan station was started as an experimental plot for coffee, Kramers (1900, p. 76) thought it would be very important to test various shade trees there. A number of fields were planted towards the end of 1910 with a set of 22 different such species that originally had been chosen by Kramers. Among these was Leucaena glauca. Kramers said that the tree was frequently planted in western and central Java as a hedge and for firewood. It is a small tree, and the tallest specimen he knew was only 10 to 12 m. high. He added that he had no experience with its suitability as a shade tree but that the growth of the crown made him think it might perhaps be suitable if it were only quick enough.

The earlier history of Leucaena glauca as a shade tree has been published by Ultee (1935a, p. 1094), who found in a note on coffee planting at Kandangan by de Vogel (1895, p. 11) that the tree called "kolomtoro" there was planted wherever dadap would not grow well. It was unsatisfactory as

a shade tree, since it grew too slowly and was too low. The high altitude of Kandangan appeared responsible for this slow growth. Afterwards Ottolander mentioned it (1905, p. 82) not as a shade tree but as a supply for reforestation of denuded spots and for keeping lalang grass down. The first time it was mentioned in public as a shade tree was by van Lennep (1907, p. 695) at the Ninth Coffee Planters' Conference in Soerabaja after he had seen a plot of it at Bangelan. During the discussion after van Lennep's lecture it developed that lamtoro had been successfully used on an estate in east Java in Soember, as a shade tree since 1902 (loc. cit., p. 704). Ultee referred to this older literature and concluded that this was the same year when Bangelan started an experiment with L. glauca. This is, however, a slight error, since at Bangelan the new shade tree was planted in 1901. It appeared in the report for that year (under the native name of "Kemaladangan") on p. 116, under shade tree experiments (Jaarverslag, 1901).

Soon Kramers' choice appeared to be a very good one. In a few years the field under Leucaena glauca surpassed all the others in healthy appearance and yield.

The visits of planters to the station spread the good word about L. glauca even more than the regularly published notes in the annual reports, and from about 1905 on the tree attained great popularity. In a few years it became the most frequently used shade tree. There is no doubt but that the difficulties which planters had with dadap and Albizzia made them look for a suitable tree to replace the older kinds, and this Leucaena called "lamtoro" promised to fill the bill. It has fulfilled its promise completely, for up to the present day it is the most generally planted shade tree in Indonesia; and its service is everything that the planters could ask of a shade tree.

Leucaena one of the Mimosaceae, called "lamtoro" in Indonesia, is a small tree with a strong, tough, somewhat flexible stem, and a small candalabra-like crown with finely divided leaves. It retains its foliage well during the dry season. It stands heavy pruning and even repeated stumping. It can be multiplied easily by seed, of which it produces large quantities. Lamtoro can be used as a shade tree as well as for green manuring. Sown in rows, the plants can be cut regularly and will throw out new stems every time. At Bangelan the species was generally used for planting the edges of the terraces to keep the soil together and to protect the young coffee from wind during the dry season. Moreover, the wood makes an excellent firewood, and when the pruning and cutting of stems is carefully done, a hectare of lamtoro in coffee will produce more than enough firewood for factory drying of the crop produced by the same plot.

The lamtoro tree is rather low, and this makes it suitable for combinations with all kinds of trees with a loftier crown, such as dadap and Hevea. This latter quality has surely contributed to its popularity in the years when rubber was planted on a large scale with a catch crop of coffee. In addition to all these qualities the tree has a favorable influence on coffee. In the comparative tests with various shade trees at Bangelan, the field with coffee under lamtoro always struck visitors with its excellent appearance, and the total yield was the highest of the set for years. Kramers had a stroke of luck when he included Leucaena in the list of species tested, and it has often been said that this discovery alone made up for all the expenses of the station.

This was not said from the first. In the beginning, the new kind of shade was not considered very promising. The growth in the early stage was not very vigorous, and the early flowering was noted (Jaarverslag, 1903, p. 145). In 1905 (Jaarverslag, 1905, p. 153) the report was more favorable. Although the lamtoro trees were still small in May 1904 (3.5 m. high), in 1905 the field surpassed the neighboring ones with respect to the appearance of the coffee. The report for 1906 was still more enthusiastic, and the yield of the coffee was high and the trees did not suffer from rust. The value of the new shade tree was considered proven, and it was used from then on in all fields for replacing dead dadaps. In the report for 1907 attention was directed to lamtoro. The coffee under it was remarkable for its excellent stand and was among the best yielding plots (Jaarverslag 1907, p. 192). The value of the new shade tree could not be overestimated. Stand and yield of the coffee under it were exceptionally good (Jaarverslag 1908, p. 94). The report in 1909 was still favorable (Jaarverslag 1909, p. 187) and was accompanied by a photograph of the field, then 8½ years old. The new kind of shade tree had already established its reputation firmly, and it was moving into first place among shade trees with respect to popularity.

An enthusiastic admirer of lamtoro (Alberts 1915, p. 4) enumerated its qualities as follows: (1) excellent nitrogen collector; (2) fast growing, with hard, strong wood -- a rare combination; (3) healthy constitution, not susceptible to diseases and pests; (4) not damaged by windstorms as it had a deep tap root; (5) thornless, easily pruned; (6) always in leaf; (7) regulator of light and air, since the leaflets fold up at night and under a clouded sky; (8) source of timber for field bridges, posts for natives' houses, and firewood; (9) great rejuvenative power, can be cut time and again and always shoots once more. No other shade tree has been found that possesses so many virtues.

Some 15 or 20 years later another quality of lamtoro was studied. It is one of the Leguminosae,

forming not only the nitrogen it requires for itself by the root nodules but also yielding very considerable quantities of it to the surrounding soil. Experiments with various cover plants cultivated next to three coffee seedlings in tins with sand showed that lamtoro was able to excrete appreciable amounts of nitrogen from the root nodules into the soil. Under circumstances favorable to the fixation of nitrogen the quantities excreted were sufficient to raise the N-content of the coffee leaves and make the plants grow better than the control plants (van der Veen 1940, p. 131). In a comparison cited from Huitema (1935, p. 189) it was found that the greater proportion of lamtoro roots developed in the subsoil, with only 43 per cent in the top layer where the coffee roots spread. This fact explained partly why coffee did not suffer from root competition when growing lamtoro, and van der Veen concluded from his experiments (1940, p. 130) that the absence of an unfavorable effect on the coffee roots or at most a very slight one, was a positive quality of the lamtoro roots, since both kinds of roots grew densely intermingled in the small space of the tin they occupied without doing any harm to the coffee.

It is known that lamtoro also has its drawbacks. One is its prolific seed production, since the seeds sprout and become a weed under the coffee. It has been suggested that the seed be collected, ground, and the meal used as organic manure. A greater objection is that its heavy flowering offers a good shelter to coffee pests, especially dompolan lice. The plantings of seedless or nearly seedless trees with vigorous growth offered a possible solution to this difficulty. According to an oral report by Endert, lamtoro presented another danger in very dry regions, since the dry fruit is inflammable, a point observed in lamtoro used as shade for coffee. This was another point in favor of the seedless kind.

In 1933 Huitema (1933, p. 680) published a good historical review of the occurrence of nearly seedless Leucaena glauca. The first time this type was observed was at Bangelan in 1912. Since the seedlings raised from the few seeds occasionally found on the seedless variety did not run true to the type of the mother, Huitema tried vegetative multiplication in the Cultuurtuin in Bogor by propagation on cuttings, by budgrafting, and by marcottage. The last method was fairly successful. Huitema also described the differences between the seedless type and ordinary lamtoro. The stem is straighter, and the canopy is larger so that a greater quantity of leaves is dropped. The color of the leaves is lighter, and there are also morphological differences between the flowers of the two kinds.

At Bangelan, various methods of grafting seedless lamtoro were tried and were fairly successful (Blankert 1933, p. 675). In 1934 Hoedt returned to the seedless lamtoro (1934, p. 1210). Prillwits (1935, p. 441) had found a method for obtaining a high percentage of success with the budgrafting of lamtoro. The best and simplest method was found to be patch budding. Three or four days before budding a small strip of bark of the stock was removed about three centimeters above the point where the bud would be put, covering $\frac{3}{4}$ to $\frac{4}{5}$ of the circumference of the stem. The buddings were then bandaged with a strip of dried leaf of the fibre banana, and the bandage removed a fortnight later. One month later the stock was cut about 2 or 3 cm. above the bud patch. If the bud did not show further development after one month, the ringing of the stock was completed, and 3 or 4 days later a second budding was made opposite the first. A detailed description of the successive manipulations of the method are given in the article.

L. glauca has also another type which shows increased vigor. At first it was thought to be a hybrid with an acacia, but later it was considered a variety. It was found among seedlings at Soember Agoeng, among which 132 plants of the new type could be identified. The variety proved true to seed. The growth was much more vigorous, the stem straight, and the branches more erect. After 2 years it was already a nice shade tree. The new kind gave few seed. (Celosse, 1940, p. 526).

OTHER LEUCAENAS

A new, promising line for securing a lamtoro without seed was studied by the Forestry Research Institute in Java when it introduced some new species of Leucaena, viz., L. pulverulenta and L. glabrata. The latter did not flower except in one case on an estate in a very dry climate and at a high altitude. In 1938 the Forestry Institute found that if it were stumped, the new shoots flowered and produced seed. Years later Lammers (1940, p. 1168) studied the material introduced into Java and came to the conclusion that the material originally introduced was already heterozygotic and, further, that L. pulverulenta hybridizes easily with L. glauca.

The seedlings from these could be classified into 4 groups: (1) plants which never flowered and which developed vigorous trees with a thick, dark green foliage; (2) plants which flowered and set fruit until they were 6 months old and which developed into vigorous trees with a thick, dark green foliage; (3) plants which flowered until they were one year old, but not heavily, and which showed vigorous growth with a strong stem and light green leaves; and (4) plants which flowered and fruited heavily until they were at least 18 months old, perhaps longer, but with a moderate or bad

growth, a weak stem, and light green leaves. Several sub-groups could be distinguished in the latter group. The percentage of groups (1) and (2) was rather small so that multiplication by seed was not desirable. Out of groups (1) and (2) Lammer selected a clone with a very open crown, and this clone seems to be an improvement on the one originally distributed.

In addition, the seedlings contained another group of plants which apparently were not pure L. pulverulenta. In many ways they were intermediate between the two species L. pulverulenta and L. glauca. By bringing pollen of L. pulverulenta to flowers of L. glauca before the anthers of the latter had opened, 10 to 40 per cent of the seedlings obtained were identical with the described form. On the other hand, when seed was taken from L. pulverulenta adjoining L. glauca in two cases, a fourth of the these presumed hybrids was found. These hybrids were interesting inasmuch as they grew much more rapidly in their youth than pure L. pulverulenta seedlings. These F₁ plants could be classified again according to their flowering habits. Some trees flowered only in the first months and then no more. From these trees clones were made to study further their value as shade trees, and seedlings were also raised for further study.

The Forestry Research Institute also found a hybrid between L. glabrata and L. glauca. It was sterile but could be multiplied by budgrafting and produced quite vigorous trees. From the very scarce seed of this F₁, seedlings have also been raised. It may be expected that these new strains of lamtoro will surpass the old species by their better shade habits and freedom from lice. The difficulty that the new strains do not breed true to seed could be overcome by budgrafting and perhaps also by choosing the right stock to bud upon.

For the low coffee altitudes, L. pulverulenta is at present considered less suitable, since it grows too luxuriantly there and gives too much shade. In the higher Arabica belt L. pulverulenta is mixed with Albizzia and considered satisfactory.

The new kinds of seedless lamtoro were found of great value for estates afflicted with compolan lice. The seedless trees present still another advantage over Leucaena glauca by their far higher production of firewood (see Schweiser 1940, p. 1072). If the right policy was followed on a coffee estate, the common lamtoro gave much more firewood than was needed for drying the coffee crop produced under it. Old trees needed to be removed regularly and replaced by young ones. For a coffee crop of 1,000 q. from 300 to 350 m³ of high quality lamtoro firewood was needed for drying. About 3 q. of wet coffee can be dried with one m³ of wood. One hectare of coffee can grow about 200 trees of lamtoro 20 to 25 years old and yield 29 m³ of firewood (440 kg./m³), a figure that can be increased by about 50 per cent for the quantity cut in the course of 20 to 25 years.

L. pulverulenta (Schweiser, loc. cit.) gave a much greater quantity of firewood. This species grow vigorously at sea level as well as at 4,000 feet above sea level, and this quality made it popular. Moreover, it had other desirable qualities such as sterility, no dropping of leaves during the dry season, a very strong regenerative power after heavy pruning, and so on. The only difficulty was the necessity for multiplying by budgrafting. An experienced budder could make 120 budgrafts in a day, 90 per cent of which would be successful. Three year old lamtoro trees were budgrafted at about 5½ ft. and were planted in squares 8 by 9 ft. After 2 years the average dry weight of the budgrafts including root, stem, and branches, was 43 kg. per tree, while for unbudded lamtoro it was only 11 kg. After 4 years the budded lamtoro weighed 201 kg. the unbudded 33 kg. The author then figured that in 4 years time L. pulverulenta was able to produce a quantity of firewood equal to that produced by ordinary lamtoro in 14 years. This would be a tremendous advantage.

The hybrid between L. glabrata and L. glauca grew still faster than L. pulverulenta. The stem of two year old trees of this hybrid weighed 13 kg. against 11 kg. for L. pulverulenta. This was probably due to the pruning of pulverulenta to prevent the lower branches from overgrowing the top, and thus the tree did not develop a main stem useful for firewood. At a later age pulverulenta surpassed glabrata x glauca. At 4 years glabrata x glauca gave 34.8 kg. dry stem wood, against 51.5 kg. for pulverulenta. Ordinary lamtoro gave only 9 kg.

As a further advantage of the new strains Schweiser (1940, loc. cit. p. 1071) mentioned their taller growth. They would reach a height of 12 to 14 m. thus permitting better regulation of the shade in order to obtain a diffuse light. He considered the hybrid glauca x glabrata the most promising new kind as it allowed better and more diffuse light through than did pulverulenta. Moreover, the wood was tougher.

OTHER SHADE TREES

Apart from the main kinds just enumerated, there are certain other species of shade trees which have been tried from time to time. Some have been found to be fairly good but were later replaced by more popular ones. When Bangelan started its testing of shade trees the list included 22 names, among which was Indigofera natal, more a green manurer than a shade tree. It was soon replaced by dadap. The plots were about ¼ ha. and coffee was planted in plots of 7 by 7 ft., the shade

trees in plots of 21 by 21 ft. Various jungle trees were found unsuitable, viz., Laportea amplissima the kimadoc broenia; Trema sp., the angroeng; Melia asedarach, the mindi; Macaranga tanarius, toetoe merah; Mallotus ricinoides, toetoe poetih; some rubber producers such as Castilloa elastica, and Manihot glaziovii; Cedrela odorata; Parkia intermedia; Sesbania egyptiaca, djanti; Caesalpinia dasyrachis; and Cedrela serrulata the soerian. In 1907 some of these plots were reopened for other plantings (Jaarverslag 1907, p. 192). In 1908 (Jaarverslag 1908, p. 94) an additional group of unsuitable kinds was listed. In 1911 the whole experiment was finished. Wurth, at that time the supervisor of the station, published in the annual report for 1911 a table giving the annual yields per hectare of the coffee in plots with the principal shade trees that were more or less suitable.

While shade had long been considered universally necessary in Indonesia, in east Africa it was one of the most debated questions connected with coffee planting (McDonald 1930, p. 44). Various kinds of shade trees were discussed, and the one most strongly recommended by the Agricultural Department was Gliricidia maculata. Grevillea robusta was much used in east Africa, but without many advantages (loc. cit., p. 47).

In addition to the kinds of shade trees tested in Indonesia in Bangelan, a few others may be mentioned which have enjoyed a temporary popularity or have been tried for a while. In the old days Caesalpinia dasyrachis was considered promising, and it was used for some years around the turn of the century in the Economic Garden in Buitenzorg with satisfactory results (van Romburgh 1899, p. 483). The growth was rather slow and the stem crooked when mixed with other kinds of shade trees. At Bangelan it was not a success, and Celosse (1933, p. 452) rejected it for its slow growth.

In the Economic Garden and in a neighboring coffee field, good results were obtained with Deguella microphylla (Anon. 1905a, p. 316, with plates). It was distributed from there to the estates, and there was such a keen demand for seed that many who wanted it had to be disappointed. Thus it was thought worthwhile to point out that Deguella could also be multiplied by root cuttings (Cramer, 1909e, p. 238). The reports received on it were generally favorable (Jaarverslag proeftuin; Jaarboek, 1908, p. 77), but at Bangelan it was not much of a success. Celosse (1933, p. 452) noted its being planted somewhat more extensively, but he complained about a caterpillar which ate the leaves in the dry season just when the shade was most needed. Some years previously Acacia multijuga had been recommended, but Celosse considered it unsuitable except as a belt for protecting tea fields on a slope against sharp winds in the dry season. Gliricidia was tried, but it never could get a firm hold. If all the kinds of trees tried as shade trees and rejected were enumerated here, we would have a long list.

A good deal of data on the older ones is contained in a general review of the shade problem by Ottolander in 1905. He summarized the answers received to an inquiry on the shade problem from 90 estates. He concluded that coffee in Indonesia required shade but that the degree of it depended on the climatic conditions of the estate. The problem was more complicated than reduction of light alone and involved protection from wind, levelling temperature differences, counteracting erosion and excessively rapid decomposition of the top soil, addition of humus, and supplying nitrogen. After being planted for two centuries dadap was on the decline. The cause might have been degeneration by continued vegetative propagation over too long a period, and there was no doubt that diseases and pests had increased. In the discussion it was mentioned that on one estate seedlings were raised and that some beautiful plants were found (Stibbe 1915, p. 218), but that cuttings from them were as susceptible as the rest. After some further discussion of this point Ottolander recommended further introduction of new kinds of Erythrina. The temporary use of auxiliary shade trees, with or without dadap, was advocated, and Albizia was praised with the warning that it should be rejuvenated before the trees got too old. A list was then given of other trees suitable for windbreaks, and as a last group, some kinds not suitable as shade trees but good for reforestation of denuded slopes, for fighting lalang, and so on, were mentioned. It was in this last group that Leucaena glauca was placed.

The use of lamtoro as a green manure has already been discussed. In young coffee plantings the term "auxiliary shade" has sometimes been used for plants put out between the young coffee trees, mainly for protecting them in their first year during the dry season and for protecting them from wind. Since the coffee is still small at that time and the protection only of a temporary character, it is, so to speak, a transition to green manuring. Bushy green manurers can be used for this purpose. Sometimes "rorako", Ormocarpum seneoides, is used in this way. This leguminous shrub has the advantage of being easily multiplied by cuttings (van Helten 1915a, p. 31). Rorako has been used on land where lamtoro would not take at first. After planting with rorako the Leucaena took hold (van Helten 1915a, p. 27). However, in a later publication rorako is criticized as becoming woody too soon for a green manurer (van Helten 1924, p. 49).

TREATMENT OF SHADE

An important point in coffee growing is the treatment of shade. In the first place it depends on the kind chosen and then on the climatic conditions. The phytopathological situation may also force the planter to take certain measures at times in regard to shade.

Generally speaking, in Indonesia, all shade trees must be pruned. In the rainy season there, less shade is necessary than in the dry months, in low altitudes less than in the higher belt. At the greatest altitudes above sea level it may be found that coffee requires so much protection by a heavy shade that it is necessary to establish the shade trees first and the coffee not earlier than two years later when the well advanced growth of the shade trees creates a favorable medium for its development.

In the lower belt the pruning of the shade has a decided influence on the yield of coffee trees. The ideal should be to keep the shade just dense enough to prevent any overbearing, but as Celosse has remarked, it is easier for the experienced planter to see when there is too much shade than when there is too little shade. The conclusion is that the planter should never let the shade alone, but by pruning and permitting new growth, cutting out and replanting young trees, he should vary his shade constantly to increase or reduce it as the situation might demand. The influence of the degree of shade on the flowering and yield was studied in a preliminary experiment by van der Veen (1934b, p. 1063), who found that a large quantity of sunlight gave a large flowering. The condition of the shade in the beginning of the rainy season influenced the early blossoming before the main flowering, which depended on the shade in the second half of the rainy season and in the beginning of the dry season.

A clever system that can be applied simply is based on the principle of keeping the shade moving. It was developed by an east Java planter, Alberts (1915). Lamtoro was planted at double distance from the coffee trees (5 x 5 m., coffee $2\frac{1}{2}$ x $2\frac{1}{2}$ m.); and when the coffee was adult, alternate trees in every other row of lamtoro were stumped annually at 10 feet, one year the first, third, etc. trees in the even rows, the next year the first, third, etc. trees in the odd rows, then the second, fourth, etc. trees in the even rows, and so on. This was done in the beginning of the rainy season, and the effect was that the coffee was always protected at the beginning of the dry season by a roofing composed of lamtoro crowns 6 months of age, 18 months old, $2\frac{1}{2}$ years, and $3\frac{1}{2}$ years in equal proportions. In a later note the same author (1924, p. 432) stated that he continued his pruning system and that 9 years after his first description of the system the trees did not show any harm from the repeated heavy pruning.

If less shade were desired in lower altitudes, the cycle would easily be modified so as to obtain such a result. In the experimental plot at Kaliwining, half the lamtoro was topped annually. When it was done for the third time, the cut was made under the place where it was made the second time, since otherwise too many small twigs sprouted near all the old cutting spots (Gandrup 1935a, p. 187). Another modification was to not cut the whole crown but to thin the branches heavily so as to obtain candelabra trees. The advantage of the nearly automatic system is not lost. When several kinds of shade trees are mixed, the same principle can be applied aiming at keeping a regular shade by constant removal and replacement.

The systematic treatment of shade, must take local conditions into account. On the very sandy soils and in the climate of the Kelod mountain a very dense shade in the dry months was required and when the stand of lamtoro was sufficiently dense a good system was to pollard all or part of the trees at 4 meters in the beginning of the rainy season and let them form a dense new crown (Snoep 1936e, p. 236).

A rational method for the mixture of dadap with lamtoro was worked out by Rudin (1930, p. 221) with a 12 year cycle. This mixture was useful for keeping a dense shade on estates which had to fight attacks of *dempelan* scales. Experiments with plots of lamtoro alone were compared with plots in which the mixed shade, lamtoro and dadap, were planted, and they showed a heavier attack on the former (de Fluiter, 1936a, p. 772).

The use of the mixtures led to a system under which a "three storied" roofing of shade was established: the lowest one of lamtoro, the middle of dadap, and the top Albissia. This system was well applied in Arabica coffee plantings. The regulation of the amount of shade was managed by the pruning of the lamtoro and dadap (Vraagbaak 1941, p. 97). How important the mixture of lamtoro with Albissia was from the standpoint of pests, especially white scale, appeared from the observation that on the Idjen plain this pest only became serious when the old Albissia trees were cut about 1925 (de Fluiter 1936a, p. 775).

CHAPTER 14
COFFEA ARABICA

CHARACTERISTICS

Coffea arabica is a shrub or small tree. The stem, with greyish or light brown bark, bears many thin, flexible branches with dark green, shiny leaves 10 to 20 cm. in length and a half to a third of their length in width. A full description of the characteristics with data on their variations for many mother trees may be found in Cramer (1913, p. 126). The flowers are white, sometimes with a very light shade of pink at the base of the tube. The tube is 6 to 10 mm., with 5 to 7 lobes which range from 12 to 14 mm. in length. The time between flowering and ripening of the fruit is shorter than in other coffee species, generally only 7 to 10 months. The berries are about 15 mm. long, dark red and oblong in shape, with nearly straight sides. The proportion of ripe berries to market coffee varies from 5:1 to 6:1, sometimes 6.5:1. The percentage of round beans varies around 10 per cent, and sometimes it is as little as 2 to 4 per cent. The parchment skin is thin, paperlike, yellowish grey. The freshly pulped beans are whitish. The silverskin separates easily from the dry bean, even after sun drying. The market product may be in various colors -- grey, green, blue green, grey blue, green grey, and, after a long storage (which is said to improve the flavor) brown to golden brown such as the famous old "Preanger doré". On the whole the aroma is very good. The beans are rather variable in length. Estates at high altitudes may produce a large bean averaging 0.2 gr., but the average goes down to 0.14 gr. for smaller beaned C. arabica.

This species has been reported as indigenous in various parts of Africa; but, according to more recent investigations by Aug. Chevalier (1939, p. 397) who compared material from various herbaria such as Kew, Berlin, etc., several specimens described as C. arabica belonged to other species, such as C. canephora Pierre. The C. arabica is found in the wild state only in the mountains of central Abyssinia, in Goré and Kaffa, at 1,500-3,500 m. in small, narrow valleys with tributaries to the Blue Nile and the Omo (Chevalier, loc. cit.). Another author (Tissot 1938, p. 409) stated that the region where C. arabica originated in Abyssinia is the high plateau between 1,500 and 2,000 m. where there were two rainy seasons. In its natural state it existed as undergrowth in the forests (Kramers 1904, p. 71) on the slopes of the mountains at several thousand feet above sea level. Coffee appears as indigenous in the voïna déga between 1,700 m. and 2,300 m., with 500-1,000 mm. of rain per annum (Tissot 1938, p. 401, 409). It has long been cultivated in the province of Harrar at 1,200 m. above sea level. In Abyssinia the leaf disease has been commonly found on the coffee, but even in the places where it was most frequent some plants showed resistance (Castellani 1938, p. 337). Chevalier described (1929, p. 132) the climate in the country of origin of C. arabica and cited a figure of 1,000-1,500 mm. for the total annual rainfall in the high plains of Abyssinia.

Some curious particulars on C. arabica in Abyssinia, are given in a little known article on agriculture in that country by Kostlan (1913, p. 235). He made a distinction between two kinds of it. The first was Harrar coffee, which existed only as a cultivated plant, growing around Harrar on a fairly large scale. This kind had been introduced by old Arabian immigrants in Harrar. The seed of Harrar was described as large and of a beautiful green color. The second kind was called Abyssinia coffee, and the color was also a beautiful green but with much smaller beans, and of a strong flavor. He considered it a wild product. Most of it was collected from wild trees in southern Abyssinia, but the crop of the wild trees was far from being entirely harvested. It was also produced in numerous plantings cultivated in a primitive way in the neighborhood of the native villages. Although the trees did not receive the care given to the plantings in Harrar, the product, had a very good quality.

The C. arabica from Abyssinia consisted of various kinds. Tissot (1938, p. 409) mentioned four different kinds, among which was Zéghié (from Goggiam) with small beans and a special flavor. It was exported through Khartoum.

It appeared that sometimes the fields were irrigated, they were at an altitude of about 1,500 m., and frequently the young plantings were manured with sheep dung. Shade trees were not planted. The yields were described as 15 to 20 kg. berries per tree for younger trees and 20 to 25 kg. for trees 30 or more years old. According to Bieker (cited by Chevalier 1929, p. 6), coffee was cultivated in the jungle of the Kaffa province of Abyssinia in small plantings in the forest or in gardens near the houses where the shrub was mixed with other trees which provided shade.

In those parts of Java where the best Arabian coffee estates are situated, the altitude is about 1,000 m., with an average annual rainfall of 2,343 mm. to 2,500 mm. For example in Pantjoer the altitude is 985 m. and rainfall is 2,343 mm. In Kajoemas, 1,060 m., rainfall 2,535 mm. The other nearby region of the high plateau of Idjen is dryer. Figures for the coffee estates there are: Blawan 900 m., rainfall 1,597 mm., Kalisat, 1,100 m., rainfall 1,636 mm. (Braak 1921a, p. 19). If the climate of the Arabian belt in Java were to be compared with that of other countries which produce

Arabian coffee, a certain similarity may be found. The annual rainfall for Harrar in Abyssinia, 1,860 m., is 895 mm., for Juiz de Fora in Brasil, 675 m., is 1,579 mm. (Braak 1921a, p. 492).

In Indonesia, C. arabica, called "Java coffee" and once the most important product of that island, became of secondary importance for the export trade. The area covered by it now is very small. The "Java" coffee is still produced by some estates on volcanic soils in the most easterly part of Java on the Idjen plateau and neighboring ridges. Since it lost its commanding position the total area of estates, Arabica in Java has shown little increase (Centraal Kantoor 1931, p. 142). In 1930 it comprised 3,924 ha.; in 1939 it covered 4,265 ha. including young plantings, with a total yield of 1,866 tons in 1939. This latter was the biggest crop in the last decade. In 1938 the yield was only 1,198 tons for 4,077 ha. (Centraal Kantoor 1941, p. 145). A few estates outside of Java and some native centers in the outer provinces, all in the higher altitudes, as central Celebes, Bali, and northern Sumatra, also produce Arabica.

In the principal producing countries, C. arabica is known to include several types with divergent morphological characteristics. Cramer (1913, p. 129) described several forms found in Java which were considered to belong to the typical group but which showed a fair range of variation and other forms which already constituted a transition from the typical form to well defined varieties. However, the latter had not progressed far enough to be included with these varieties. Different types have been grown in other countries. In Brazil at least two, the Nacional and the Bourbon varieties, have developed even further variation such as the yellow-fruited "loss" variety. Dafert (1899, p. 24) mentioned the "Café commun" as a coarse strain, well fitted for extensive planting, while the "Café Bourbon" was considered by him to be a finer variety, preferable for intensive cultivation. The C. arabica cultivated in Colombia has shown multiple forms which seem to have developed in that country by an adaptation of the typical plant to the conditions of a special site (Sladde, 1931, p. 310). Apart from such forms showing divergent physiological and often even divergent morphological characteristics, there were striking differences in productivity between trees in the same field.

In British East Africa different types of C. arabica are also found. The Kenya coffee originated with the importation of Mocha by the St. Austen's Mission near Nairobi in 1900 (McDonald 1930, p. 27). French, a well known coffee expert there, is cited as saying that there is no uniform variety. Several "bronze tip" varieties are mentioned. According to Stoffels (Stoffels 1936, p. 41) the plantings of Arabica in Kivu are composed of a mixture of forms. This polymorphy leads to a certain number of variations which will be noted later. Some closely allied species have also been discovered with Arabica, which are described in the next section.

CLOSELY ALLIED SPECIES

Before discussing data about the cultivation of Arabica in Indonesia, a note may be inserted here on a few new species of coffee which seem to be closely allied to C. arabica. These were discovered in central Africa in the mountainous region near Lake Kivu. They were described in 1933 by the Phytopathological and Agriculture Services of the experiment stations which were then under the supervision of the "Société Auxiliaire Agricole du Kivu" and are now included in the network of stations of the Institut National pour l'Etude de l'Agriculture du Congo Belge, called I.N.E.A.C. by many.

Two species were described, C. kivuensis Lebrun and C. van roecheodtii Lebrun. Both showed only small differences from C. arabica, and these were not clearly defined in the descriptions. The general aspect of the trees in the virgin forest was very different from that of cultivated trees, but so would the appearance of ordinary Arabica be different if grown under such conditions. The leaves of C. van roecheodtii seemed of about the same size as those of C. arabica. The C. kivuensis had smaller leaves. In the descriptions of the length of the leaf lamina, measurements of 10 to 13 mm. were given for C. kivuensis, of 11.5 to 15 mm. for C. van roecheodtii; but "mm." is clearly a typographical error for "cm.". The width of the leaves of the former is 3.5 to 4 cm., for the latter 4.3 to 5 cm. The berry of C. kivuensis was described as ribbed, less club shaped, and firmer than that of C. van roecheodtii. The fruit was considered as slightly larger than that of Arabica, 18 to 20 mm. for C. kivuensis, 19 to 21 mm. for C. van roecheodtii.

Some slight differences were given between the two new species. C. kivuensis with a 5 lobed corolla and a truncated calyx; but C. van roecheodtii with a 6 lobed corolla and a dentated calyx. C. kivuensis was found on Mount Kakuzi, Kivu, between 2,100 m. and 2,300 m., while C. van roecheodtii was found at Mushwere (near N'Gweshe), Kivu, at 1,900 to 2,000 m.

The two species were unquestionably indigenous and had not escaped from cultivated fields. This was proved by several facts as follows. They showed growth characteristics different from C. arabica; many specimens found were 30 to 48 years older than the first introduction of C. arabica into the district; and they were uniformly spread in an extensive stretch of forest, more or less

regularly disseminated over a distance of about 15 km. in the whole wooded area at an altitude of 2,150 m. The trees of C. van roechoudtii appeared to prefer steep slopes near brooks, and they were less common than C. kivuensis. In some places the latter was so common that trees were hardly 30 to 40 meters from one another. Its stems grew to 8 m. in height and often bent over. In the case of C. van roechoudtii the tree was straight-stemmed and smaller attaining a height of only 4 meters.

The trees of these new species did not show any traces of attack by Hemileia. Some of the berries were attacked by a borer and perhaps by the microlepidoptera, Eucosma. Larvae of Ceratites capitata were found in the pulp of ripe berries (Services Phytopathologique et Agricole, 1933, p. 17).

The new species were introduced in the experiment station at Mulungu, but annual reports did not give details on them. They were put into nurseries on estates, but showed weak growth there. They seem to have been of considerable interest, since there can be no doubt that they are different from the typical C. arabica (Services 1933, p. 17). The altitude where they occur corresponds with the higher altitudes where C. arabica is still grown in the Kivu region. Other species not far removed from C. arabica are C. congensis, C. stenophylla, and, especially, C. eugenioides. Some of the types of this last species resemble the dwarfed, small-leaved varieties of C. arabica.

The plants described as C. arabica var. intermedia Froehner may also be a species closely allied to but different from C. arabica. Froehner (1898, p. 264) described it as having smaller, narrower leaves than C. arabica. It grew in the African Lake region (Ligaijo). Samples which are probably identical came from Chiradzulu and Ruwensori. According to de Wildeman (1910, p. 362) the sample from Ligaijo showed domatia resembling those of C. arabica.

YIELD FIGURES

Yields of Arabica in Indonesia, were estimated in the old days as averaging 10 piculs per bahoe, equal to about 8.7 q./ha., for a good estate (Berkhout, 1893, p. 76); but after leaf disease made its appearance in Indonesia, this figure decreased. Van Delden Laérne was more conservative about the average yield of this coffee in 1885 (p. 511). According to an insider the yield in east Java for the period from 1897 to 1901 was not more than 3 piculs per bahoe (2.6 q./ha), while it was once about twice this figure (Suermondt 1901, p. 291). Even lower estimates have been made for those years (Renardel de Lavaletter & Schol, 1902, p. 363). In a note dated a few years later, however, it is said (Indische Mercur, 1904, p. 69) that yields of 8 to 10 piculs per bahoe (7-9 q./ha.) were not rare. The yield of the best estates in east Java later averaged hardly more than 5 q./ha. In 1916 Cramer estimated (p. 205) the yield of the "best Arabica estates of Java, with excellent upkeep and careful picking", at an average of about 5.5 q./ha. (Vink, 1929, p. 51). In 1928 a yield of 4.2 to 4.5 q./ha. was considered satisfactory for the Idjen estates, and it was thought that a greater yield should not be forced (Frontou 1928, p. 70). Shortly after that, Schweizer mentioned (1931a, p. 57) that there were still fields of Arabica where 10 to 15 piculs per bahoe (9-13.5 q./ha.) were produced without damaging the trees. In southern Sumatra in 1899 yields were estimated for estates enjoying very favorable conditions at 7-9 q./ha. for fields at a higher altitude, at 9-13 q./ha. for lower fields (Ind. Mercur 1899, p. 287). A planting of 100-150 ha. in Sumatra gave the following yields: 1896, 10 q.; 1897, 7.3 q.; 1898, 3.7 q.; 1899, 3 q. (Kissing 1900-1901, p. 106). For the period 1905-1917 the annual yield for a good estate in southern Sumatra was calculated to average 6.69 q./ha., with 5.19 q. as the lowest and 10.89 q. as the highest annual crop (Cramer 1918, p. 20).

In southwestern Sumatra attack by Hemileia did not appear to have the same disastrous effect on C. arabica as it had had in Java. However, in 1936 there was only 60 ha. of estate Arabica left in this province, since the yield had gone down to 2 or 2.5 q./ha., although some estates had good crops yielding up to 7-10 q./ha. in the earlier years of their existence (Keuchenius 1936, p. 7).

Of all the kinds of coffee planted in Indonesia, Arabica gives the lowest yields, but this drawback is compensated by the high quality of the market product and the consequent higher prices. The success or failure of the crop of this species is greatly dependent on weather conditions, and therefore it is very capricious from one year to another. When it was still widely grown in Java, the total annual crops showed great variations, even while the distribution over many districts more or less levelled the total figure. A striking case of this capricious cropping was noted by an estate in east Java, which in one year, after an optimum flowering season, produced 8,000 piculs, but only 200 piculs the next year! It is easy enough to draw up a table for the yields for subsequent years until the adult state is reached, but it is feared that such a table would give the wrong idea of the real situation to a reader not acquainted with the capricious bearing habits of C. arabica.

THE SO-CALLED DEGENERATION

The term "degeneration" was not used to describe the expulsion of C. arabica from the lower

belt, where it once flourished, for this occurrence was simply a result of the leaf disease. In the days of the East Indian Company, Arabica was planted near Batavia, and Burck (1896a, p. 315) recorded plantings only a few feet above sea level. Burre Boere (1900-1901, p. 294) mentioned that in 1900 he saw a 50 year old planting of C. arabica near the beach at Banjowangi and that it had given large yields when still young. Burck (loc. cit.) also cited plantings of C. arabica at sea level in several places in Java. This was all before Hemileia appeared. After it invaded Java in 1800-1885 this coffee was driven back to the middle and higher belts, but even in 1899-1900, Ottolander (1936, page 360) considered an altitude of 2,000-3,000 feet and a soil rich in humus as still quite suitable for this coffee.

In the later years of the nineteenth century, however, planters started to argue that fields of Arabian coffee planted in the same way and kept under the same conditions as those of 15 to 20 years earlier, gave much smaller yields. In 1876 Thurber (1881, p. 65) visited one of the finest coffee estates of Java in the Preanger district. In average years it produced about 9 piculs or 5.5 q./ha. In 1900 van Lennep (1900-1901, p. 32) complained that fields then yielding 8 or 10 picul per bahoe (7.5-9 q./ha.) suffered from overbearing; and he referred to Morren, who stated that fields yielding 12 to 15 piculs a decade earlier still produced well, but that younger plantings that were only 6 to 7 years old gave only 4 piculs per bahoe. Trees 15 to 20 years old at the time, yielded 12 to 15 piculs fairly regularly, while in 1900 the average yield was 4 to 5.

We will note a little further on that Vogler calculated data on a fair number of Arabica estates in east Java over 10 years periods and found that in 1881-1890 and 1891-1899 the average yield was 5 to 6 piculs per bahoe. For the period 1898-1903 Kramers (1904, p. 38) estimated the average annual yield for his experimental fields at 4 piculs per bahoe (equal to about 3.5 q./ha.) and considered this above the average. This regression in productivity was attributed to lack of seed selection. The discussion at a planters' conference led to a proposal to start a company for producing improved seed (Graichen 1900-1901, p. 37). Another planter, Vogler (1900-1901), was of a different opinion. He denied that planters did not apply selection. He concluded that there was no change in the coffee itself, giving as an example a young planting of his planted with seedlings from trees on his estate. At the end of the third year and after removal of about half of the crop it gave over 5 piculs per bahoe (4.5 q./ha.). He felt that if coffee showed less resistance, the cause was probably a change in the external conditions.

Vogler also collected data from well known estates in his district opened about 1880 and, thus having gone through the well remembered Hemileia year of 1885; he showed that their production averaged not more than 5 to 6.5 piculs per bahoe (4.5-6 q./ha.). He also compared average yields of "old plantings" entering production in or before 1890 and of younger plantings where this stage was reached later. For 13 estates with old plantings, an average of 5.8 piculs per bahoe for the period before 1890 was determined, with 2.66 piculs and 10.86 piculs as extremes; and he found an average of 5.6 piculs for 1891-1899 with 4.49 piculs and 8.09 piculs as extremes. For 7 young estates for the period before 1899 the average was 5.9 piculs, with 3.39 piculs and 9 piculs as extremes. Thus Vogler concluded that our Arabian coffee of Java had not degenerated.

In the discussion after the lecture some planters again insisted on the importance of taking seed only from superior trees. A planter named Halkema (see Vogler, 1899-1900) mentioned a striking instance of its good effect. If there was agreement on this point, the adherents of the degeneration theory did not give up their convictions, although they could not present data to contradict Vogler's well documented conclusion. Since that time the conviction that Arabian coffee has degenerated in Indonesia became a popular belief that was transferred to other species. The degeneration of C. liberica, which, as may be seen in the section on Hemileia, was found actually to be a gradual increase of leaf disease on this species, became a dogma. There were also rumors of the degeneration of Robusta from time to time ever since the introduction of this latter species.

In the years after the discussion to which we have just referred the plea for organizing a scheme for the production of coffee seed led to the appointment of a committee which would take the matter in hand. The committee visited several estates in east Java and sought collaboration with Treub in Buitenzorg. A series of questions was put before the Buitenzorg Institute, and the decision was made to ask the government for a land grant of 140 hectares to establish good seed production plots in order to attempt a renewed introduction of C. arabica from its home in Abyssinia.

In those days van Lennep (1901-1902, p. 640) was an active propagandist for the introduction of new seed from countries with healthy C. arabica coffee that had not "degenerated". Results with plants grown from seed from Brazil made him hopeful that more vigorous strains could be obtained in this manner. After reading a report on the healthy appearance of C. arabica in Guatemala he cited that country as a possible source for better seed (van Lennep, loc. cit., p. 645). In the discussion by Vogler (1899-1900), he once more stated his opinion that C. arabica had not degenerated in Java, but van Lennep's proposal was accepted by the chairman. It is interesting to note

If a conclusion must be drawn from all the literature reviewed, it is that there is no real, internal degeneration of C. arabica. There may have been an increase in the virulence of Hemilcia, but, under ideal conditions, C. arabica growing in Java now, gives yields comparable to or at worst only slightly lower than those of 40 years ago.

that on the same occasion van Lennep showed one of his first Robusta plants. The "Algemeen syndicaat" (Coffee Growers' Association) applied to the government for permission to introduce C. arabica seed, since importation of seed was prohibited in the light of the possible danger of introducing new pests. When van Lennep gave his lecture no decision had yet been reached.

No more was heard of the seed introduction plan, but a serious effort was made to push the seed plot scheme for Java. It was to be put under the Algemeen Syndicaat. The proceedings of the Committee (Commissie tot winning van zaadkoffie, 1900-1901) have as addenda a letter from Treub dated 22 December 1900 expressing his interest and a letter of advice from Ottolander dated 27 December 1900. These records give a good idea of the general attitude toward the problem of seed selection at that time. Although several measures were prepared and a budget estimate for the establishment and maintenance of the scheme was made, it never came to fruition. A last echo of the plan to introduce Arabian seed from the outside was a proposal from the adherents of the degeneration theory to send a planter to southern India to look at the coffee there. If the plantings there proved to be healthier, coffee seed would be introduced from India (Anon., 1907b, p. 486).

Soon after these problems came up, the planting of Robusta, introduced in 1900, became known and with it the replacement of C. arabica by the new and more productive species. Attention was turned away from seed selection of C. arabica, which for most people interested in coffee became a thin of the past. Its improvement was not taken up again until after establishment of the Coffee Research Institute in Djember. A good summary of selection in C. arabica by the Besoekisch Proefstation was made by Schweizer (1930, p. 265). This work was also well described by Coleman (1931).

Difficulties in growing C. arabica increased. Formerly, the longer the dry season lasted, the more the trees suffered from over bearing, but the more moist the climate, the less this was the case. The reverse of this became the rule. A long dry period with a resting period for the tree, seemed essential for the flourishing of Arabian, while a seriously moist climate provoked failure of flowering and caused virescence of flowers, the "sterretjes" or little stars.

The plantings set out after 1900 showed a rapid and pronounced deterioration after the tenth year, although in the first cropping years fair yields of 3.5 to 9 q./ha. were obtained (Schweizer, 1931a, p. 56). However, there was no proof of any internal degeneration of Arabica. Until a little more than a decade ago, Arabian was still being planted at Bangelan, and the results did not seem poor in comparison with those of the plantings at the beginning of this century. This fact contradicts the idea of a change in the constitution of Java C. arabica.

After such early years of productivity the trees had to be abandoned and new plantings made to replace the older ones, a procedure followed in the such plantings by natives on Bali. In these plantings on this island, the trees were sometimes rejuvenated annually by bending the stems, which then formed new shoots. These could be easily reached when the harvest ripened. The planting of new fields to replace old worn out plantings was more customary in regions where sufficient land was still available, as in the Dairi district of Sumatra (Huiteema 1935, p. 168). Schweizer (1931a, p. 57) explained that on the estates in east Java the deterioration of the tree was counteracted by applying a pruning system in the earlier years to obtain very vigorous plants, sacrificing the early crop. The tree was topped until a strong undertree was formed which was then allowed to develop a shoot, generally bearing well. This shoot was taken away as soon as the undertree showed signs of deterioration.

The idea that C. arabica in Java had degenerated, survived with great tenacity. At a meeting of the Malang Planters' Association in January 1932, the chairman said that the ruin of the Java coffee, that is C. arabica, at the end of the last century was certainly associated with degeneration. There was sterility, and it was impossible to have healthy nurseries. The phenomena involved were quite different from what was being observed with Robusta (Bergcult., 1932, p. 254).

As a last echo of the degeneration of Arabian, a book on the problem that was published by Hidma in 1934 ought to be cited. Hidma (1934) attributed the deterioration of Arabica to both climatic and soil conditions. In the dry years of 1881-1884 the Java coffee produced heavily, actually above its power in the poorer districts. Thus following in 1885, C. arabica was tired. When a year of excessive drought followed the level of the ground water went down, and the plant did not get enough water. Thus it became more susceptible to diseases, especially leaf disease. The government plantings in many districts, exhausted by overproduction, could not resist Hemileia. He held that the disease did not loosen its grip on C. arabica and since then became acclimatized to the species. The disease also had its share in the ruin of the estate Arabian production. However, he felt, the latter would have come to an end without the help of Hemileia, for there were also other enemies. The limits of the forest were reached, and there was no longer sufficient humus for the Arabica to feed upon to escape the diseases.

CHAPTER 15
VARIETIES OF ARABICA

GENERAL REMARKS

Coffea arabica includes a large number of varieties, and the typical variety is also composed of many different types. Most of the varieties are parallel with those found in horticultural plants. These varieties were enumerated by Ottolander (1936, page 360). Some notes on varieties of it were published by van Romburgh (1892, p. 30). More complete data on the characteristics of these varieties were recorded by Cramer (1913). In the following sections varieties will be enumerated as they were known in Java and the rest of Indonesia in the old days. None showed an increased resistance to Hemileia rust and other diseases, and none revealed exceptional value for the industry. In the days when the planting of C. arabica was still flourishing, before the coffee crisis of 1897, very little or no attention was given to the improvement of the planting material by selection. All that was done was to take seeds from ripe, healthy berries and to reject all mishapen and round beans.

Before describing some of the varieties and subspecies of C. arabica, attention may be given to the resemblances some of its types show to variations of C. congensis and C. eugenioides, discussed in the paragraphs on these species. In this connection Vavilov's Law of Homologous Series in variation (1922, p. 47) may be cited. Although the differences between C. congensis and C. eugenioides are too great to consider them as belonging to the same "Linneon"; the same parallelism found between varieties of two or more Linneons is found here between the varieties of one Linneon and the Linneons of one group. This is in accordance with Vavilov's theory. Of special interest is his statement that Linneons and genera more or less nearly related to one another are characterized by similar series of variation with such a regularity that, knowing a succession of varieties in one genus and Linneon, one can forecast the existence of similar forms and even similar genotypical differences in other genera and Linneons.

The similarity is the more complete, the more closely the Linneons and genera are allied (Vavilov, loc. cit., p. 75).

In this connection a curious fact may be noted: C. arabica and C. eugenioides are both "highland" species, occurring at an altitude of 1,000 m. or more, while C. congensis is a lowland coffee indigenous to the lowland (up to 400-500 m.) along the tributaries of the Congo River. Nille Ris Lambers (1939a, p. 1807) developed an hypothesis that there were close alliances between the three species just mentioned and that some of their types resemble one of the other species. Another point of more general interest may be noted here. When the well defined varieties of C. arabica such as mokka, purpurascens and so on, were studied by me, it was found that in the ordinary plantings of typical C. arabica, trees could often be traced which formed a transition to these varieties, I even found it difficult at times to draw the line which should separate the trees of the typical species from those belonging to the varieties. Furthermore, I described in detail the intermediate trees which formed a transition to small leaved varieties such as mokka and two others forming a bridge to the angustifolia variety. For the bullata form I could establish a series of 5 trees for which a gradual increase of the bullata characteristic was described. After several of the descriptions of well defined varieties, such intermediate trees were also described. Seedling experiments with these trees were started, but my departure from Java and the growing importance of C. robusta absorbing the attention of the producers, broke the continuity of this work.

In reviewing the varieties of C. arabica it seems convenient to divide the forms into the more definite varieties and other improved forms. Such a division is rather artificial, but it makes the reading easier.

SMALL LEAVED VARIETIES

C. arabica var. mokka (Cramer, 1913, p. 155) is so different from C. arabica var. typica that the form, which is entirely stable from seed, might well be considered as another species. The polymorphy of the F₁ and F₂ hybrids of var. mokka with var. typica also indicates that it is a separate species. It was introduced into Java from Reunion (Bourbon), to which it had been introduced from Mokka. The note in de Lanessan (1886, p. 42) is not quite clear. It is perhaps the C. microcarpa introduced from Hes that is in Yemen, while the Café bourbon or Moka which is C. arabica is the typical C. arabica that was mentioned as precocious and already in the Botanical Garden in 1866. From 1873 on it spread over Indonesia. The growth of "mokka" is found to be compact; internodes short (2 mm.); branches stiff and thick. Leaves and flowers are smaller than those of typical C. arabica. The fruit is small, round, broader than long (8.5 x 10 cm.). The beans are small (6 to 7 mm.), hemispherical. About 1880 it was tried in several places in Java, but it was found to have no practical value. It was mentioned by de Vogel (1895, p. 10) as having been planted on Kandangan, but it had

been rejected because the small berries were hard to pick, and large numbers had to be collected to make up a picul. The hybrids with typical Java show characteristics varying from those of the parents and sometimes include plants resembling the bullata form (in F₂; Cramer, 1913, p. 168).

C. arabica var. laurina (Café Leroy or Bourbon pointu) was introduced from Sierra Leone according to the catalogue of the Botanical Garden of 1866, but this is probably an error for Reunion. It is said to be the result of a cross of C. arabica with C. mauritiana. The characteristics of the form are intermediate between those of the two species, and therefore this cross seems to be possible. It is stable by seed. In habit this kind resembles mokka. The leaves are larger than those of mokka, but smaller and of a lighter green than those of var. arabica. Young leaves of var. laurina are often nearly white; the fruit is long, slightly longer than that of typical C. arabica, and pear-shaped; seed is pointed toward the fruit stalk, beans have a particular, narrow, pointed form; also the flavor is praised.

About 1875 var. laurina was temporarily popular, but it was soon abandoned on account of its weak growth, frequently backward plants, and capricious bearing habits. The proportion of fruit to bean is unfavorable (7:1), according to Cramer (1913, p. 176). This form has the reputation of standing cold weather better than typical C. arabica. In Java this kind never attained commercial importance, but in New Caledonia the production was long appreciated (Anonymous, 1931a, p. 461). It was said to be more resistant than C. arabica to leaf disease there (Chevalier, 1931, p. 175). De Lanessan (1886, p. 42) referred to it as being quite robust and growing well without shade. Fauchere praised its taste as "exquis" (Fauchere, 1906, p. 458).

C. arabica var. murta is a small leaved variety from Brasil introduced into Java in 1884 and 1885. It disappeared and was introduced once more in 1907. The seed resembles that of ordinary C. arabica. The introduction was repeated once more by Hille Ris Lambers, who found it in the experiment stations in Africa. A few plants were permanently established in the garden of the Research Institute in Malang. The leaves of murta resemble those of laurina, but white. It was mentioned by Fauchere (1906, p. 458) for Brasil, and by de Lanessan (1886, p. 42) for Reunion. Since the few seed introduced in 1907 were said to have given characteristic plants, it is thought to be stable by seed. However, it may have been that the reports on the few plants were not exact. Cramer had to send the seed to two other places, since Buitensorg itself was unsuitable for Arabica cultivation. It is quite possible that a few nana plants occurred among the seedlings but were thrown away as too weak and that the final normal plants were considered to be due to impurities. The growth was weak, and it had no practical value. It was considered as more frost resistant in Brasil (Baretto, cited by Fauchere, loc. cit.), but without commercial importance, since the production was relatively low (Krug, 1939, p. 41).

In Brasil the var. murta sometimes showed bud variations. Carvalho (1941, illus.) described some cases and cited others from Krug. A tree of the dwarf variety nana, gave a branch with Bourbon characteristics. Another plant gave a lateral branch with murta characteristics. A third plant showed mutations at different periods affecting the entire branch, pairs of leaves, a single leaf, or even only a small area of the leaf.

On an estate in Sao Paulo in a nursery sown with seed of murta, Krug found some tiny, small leaved plants growing on the same plots among others pertaining to the variety murta and to the ordinary Bourbon. This material served for a fine study by Krug on the genetics of C. arabica. Some of these tiny plants were transplanted into well fertilized soil. At 8 years of age they were still dwarfs, and the same was true of their grafts on vigorous Maragogipe as stock. Leaves measured only 11 x 4.2 mm., and the plants were sterile. The seedlings could easily be classified into dwarfs, murta, and Bourbon. The study of the progeny led Krug to the conclusion that the dwarf type was determined by one pair of recessive factors to which he gave the symbol nana. Murta is heterozygous for the gene nana. Bourbon has both dominant factors (NaNa). The great variability observed in size and leaf characteristics is attributed to modifying genes.

Murta plants were apparently really hybrids, about 50 per cent of their progeny being identical with the parent type. The remaining consisting of 25 per cent dwarfs and 25 per cent Bourbon plants. The dwarfs do not flower, but back crosses could be made between Murta and Bourbon. These crossings gave about half Bourbon and half Murta. When the Bourbons of these were again self-fertilized, they bred true to type, and the Murtas segregated again. Crossing murta plants with C. arabica var. typica gave F₁ individuals, all large leaved, indicating the presence in the latter variety of one or more pairs of genes inhibiting the action of the dwarf gene. It appears that C. arabica L. var. typica Cramer is genetically different from the Bourbon variety in at least one pair of factors.

For the sake of completeness, variety called San Ramón should be mentioned here. It is a form with somewhat leathery leaves, smaller than those of C. arabica var. typica. It is, however, probably the largest leaved of the dwarf forms. It resembles laurina somewhat, but it does not have the white young leaves. The berry is rather short and the growth weak. It is present in some experiment

stations in east Africa and was introduced from there by Hille Ris Lambers to Java. It was grown in the experimental plot of the Malang Research Institute. There are few references to it in the literature. Listed as San Ramón miniatura it was included in Stoffels (1936) seedling experiment. (There were 8 mother trees studied; see Stoffels' Table X, p. 35). The yield of San Ramón is generally lower than that of other mother trees, and the weight per berry is also lower. However, the percentage of empty beans is also low, and the proportion of berries to market coffee is favorable, always under 4.5:1. In a comparative test the yield was low. A good photograph of this interesting variety shows a narrow pyramidal tree with dense foliage (I.N.E.A.C., 1939, p. 178). In a special experiment on poor soil the yield was fair. A close planting, one by one meter, was advised (p. 182). A somewhat similar opinion was expressed in the discussion of the results of a variety test in Puerto Rico, discussed below.

Coffea arabica var. monosperma Ottolander et Cramer is characterized by slightly smaller and much narrower leaves than typical C. arabica. In contrast with the former small leaved varieties, the branches are thin, flexible, and hanging. This habit recalls somewhat that of C. stenophylla or of the weeping willow. The trees often flower profusely, but the flowers do not bear fruit, and if a berry is occasionally found, it usually contains one empty bean. The berry is small and narrow, and the very rare good seeds are round beans, and are also small and narrow. The form is sometimes found among seedlings of typical Arabica. Cramer (1913, p. 193) once observed a tree showing the normal characteristics of C. arabica var. typica in its lower branches and only in its top part leaves resembling those of monosperma. He also described a tree of which the foliage resembled typical Arabica but which was barren. When the neighboring typical Java coffee trees were loaded with fruit, the barren tree gave only a few berries resembling Monosperma in shape. Mendes and Bacchi (1940) studied the chromosomes of the variety and found that $2n = 22$, in contrast with $2n = 44$ in C. arabica var. typica. On this point, as on many others, the monosperma form is the opposite of the bullata variety. The variety has no practical importance.

VARIETIES WITH ONE DIVERGENT CHARACTERISTIC

C. arabica var. polysperma is of unknown origin and has no practical importance. It is quite possible that it had several sources. The Dutch name ("veelzadige Menado koffie") seems to indicate that the variety came originally from Menado (Celebes). It was received in 1873 in Buitenzorg, and the characteristics proved to be hereditary there. Most of the young plants had 3 or 4 cotyledons. When the trees started to fruit in 1876, the berries showed characteristic polyspermy. A later, more extensive planting from seed which Cramer could inspect also showed normal C. arabica trees. The trees, true to type, frequently bore 3 or 4 leaves per node. The flowers were sometimes normal, and the abnormal ones had a double number of petals and 10 anthers which did not give pollen. There were a number of stigmas arranged in two whorls. The number of seeds in each fruit was 3 to 6. Cramer (1913, p. 198) found a maximum of 17 seeds in one berry, but these were all empty.

C. arabica var. bullata (Cramer, 1913, p. 210) is a curious form with broad, curled leaves with strongly undulating edges, of a dark green color on both sides. The leaf is thicker than others and leathery. Internodia are longer and thicker, and the branches are stiff, thick, and brittle. Domatia have taken the form of a small fold. The flowers are normal, petals perhaps slightly broader. Fruits vary from normal to round and broad, often many with round beans and empty beans. The vegetative characteristics just recorded also show a great range of variation when several bullata trees are compared.

In 1868 Holle found that the variety was hereditary into the third generation. It is found with some frequency in plantings of ordinary C. arabica, and Cramer (loc. cit., p. 226) also noted that it originated as a bud variation. Krug (1937, p. 406) also observed the same and the reverse bud variation by which an entirely normal branch of C. arabica var. typica originated on a bullata plant.

The variety was thought to be more resistant to Hemileia, and Cramer found this to be the case in an experimental planting on an estate in Java. However, the productivity was much lower than that of ordinary C. arabica, and the berry-market product proportion was unfavorable because of the high percentage of empty beans. The growth was weaker and the variety was therefore considered to have no practical importance. It was offered in the days of Arabian cultivation in Java as a commercial variety, and Cramer mentions plantings of it. The origin is not known.

A similar variation is sometimes found with Robusta. Seedlings of Arabica x Liberica hybrids (and the reciprocal cross) sometimes show curled leaves (Cramer 1913, p. 226). A careful investigation by Krug, who studied C. arabica var. bullata in Brasil, revealed that the form is hexaploid or octoploid.

C. arabica var. angustifolia (Cramer 1913, p. 236) has narrow leaves, the width of which are about half that of normal Arabica leaves. The greatest width of the angustifolia leaf is nearer the

top of the leaf than it is in ordinary C. arabica. Leaf nerves are less clear, and the leaf is flat. Internodia are shorter and thinner than in the typical species. The variety is stable by seed, and Cramer recorded plantings of it on estates. It was cultivated in the Economic Garden at Buitensorg, probably from trees found in the Minahassa among plants raised from seed received as "Mokka-koffie". Narrow leaved plants are sometimes found in nurseries and plantings of Arabica. The characteristic is frequently seen in seedlings of Arabica x Liberica hybrids (picture in Cramer 1913, p. 240). The variety is of low productivity and therefore without practical importance.

C. arabica var. amarella is a variety of C. arabica with fruit without the red color when ripe, showing rather a yellow tint. It has been introduced into Java, but it is not cultivated. It is probably also of multiple origin. For example, there was the planter in central Java (H. D. Mac-Gillavry of Djati Roenggo, 1903-1904, as cited by Cramer, 1913, p. 207) who found a tree with yellow fruit among his introduced C. canephora, and natives working on his estate reported that they had seen fruit of a similar color on C. arabica trees.

According to the literature, the variety is well known in Brazil ("amarella" or "Botucatu" coffee) where it was found about 1871 in Botucatu (van Delden Laerne, 1885, p. 317). According to a note published 20 years later, the variety was then considered productive by many and gave a good market product (Fauchere, 1906, p. 455). Homologous forms are known for E. robusta and C. canephora.

C. arabica var. purpurascens Cramer (Cramer, 1913, p. 201). Cramer called this species "purpurascens" in the original description 1913, p. 201. However, this was an error in spelling for purpurascens. It is a hereditary variety with red, or rather reddish brown leaves, like those of the copper beech or the red hazel. The origin of the variety in Java is not known exactly, but the Dutch name ("roodbladige Kedoe") seems to indicate that it was first found in the Kedoe Province in central Java. Cramer supposed a multiple origin for it. The variety is of weaker growth and lower productivity than typical Java arabian, and therefore it has no practical importance. Apparently the "freak tree" having all bronze or copper colored leaves mentioned for Kenya by McDonald (1930, p. 29) also belongs to this variety. According to Taschdjian (1928, p. 531), who made a seedling experiment with the variety, the green characteristic predominated over the purpurascens. The occurrence of a similar variation in C. robusta is recorded elsewhere in this present work.

C. arabica var. variegata (Cramer, 1913, p. 208) is one of the varieties with white or yellow variegated leaves such as are known in a very large number of cultivated plants. Such variations may also be found frequently in wild plants. With Coffea all species probably have produced variegated plants. Just as with other plants, the divergent characteristic often originates in a bud variation. Cramer stated that he saw only white-streaked and wholly white leaves, never white-edged ones. The heredity has not been studied. The variation is without practical importance. When variegated seedlings are found in a nursery, they are generally discarded as diseased plants.

VARIETIES OF DIVERGENT HABIT

C. arabica var. erecta Ottolander (Cramer, 1913, p. 242) is characterized by ascending branches. Leaves, flowers, and fruit do not differ from typical C. arabica. The heredity is proved by plantings of the variety on estates. Erecta trees are sometimes seen in plantings of ordinary C. arabica, and the commercial variety probably descends from such trees. The productivity was lower in a variety test on Bangelan than that of the typical species. Erecta stands wind better as a result of its peculiar method of growth. This is especially the case with branch grafts. The growth of Erecta is more vigorous than that of C. arabica var. typica. The variety has little or no practical importance. "Kent's Arabica" has yielded a variety with "chick" habit, apparently a form of erecta.

C. arabica var. pendula is a variation which shows characteristics exactly opposite to those of erecta. The branches hang down just as some pendula forms of other trees in European horticulture. An extreme case of the variation was once seen by me on an estate in Java. The tree had not formed an erect stem but was prostrate on the soil. No hereditary variety with this characteristic is known, but I have recorded an arabian tree with hanging branches, shorter internodes, and a rather high percentage of round and empty beans. In the experimental tract of the Malang Research Institute a Robusta specimen occurred with hanging of pendulant characteristic.

C. arabica var. maragogipe Froehner (Cramer, 1913, p. 254). The author's name of this variety in an earlier enumeration (Cramer, 1913) was given as Fernandes, but it should be replaced by Froehner, the correct name as used by J. E. T. Mendes (1939, p. 5). This is a well known hereditary variety spread all over the coffee growing world. The difference in growth from typical C. arabica is only slight. The leaves are not spread horizontally but hang down from the branch. The leaves are larger and distinctly broader and convex. The color is lighter green, and the flower slightly larger. The fruit is much larger than that of the typical species. It has straight sides, the seeds in the parchment are often slightly narrower in the middle, thus having a figure eight in appearance. Polycambryony is not infrequent. The proportion is favorable, and the percentage of round and empty beans

is low. The flavor is said to be exceptionally fine.

According to van Delden Laërne (1885, p. 315) the variety was discovered in 1870 by a fazendeiro of Bahia in the Maragogipe region. From there it was introduced into most coffee growing countries, in 1881 into Indonesia by the Botanical Garden in Buitenzorg. From there and by direct introduction the variety was spread over the estates. In many places in Java experimental plantings were made, but maragogipe was never planted on a commercial scale. According to van Delden Laërne, the Brazilians had divided opinions about it. Fauchere (p. 458) mentioned the low productivity as an objection, but if a well picked product was offered on the market, it obtained very high prices. The low yield was also emphasized constantly in Java. A small planting of it at Bangelan gave hardly any crop at all. Butin Schaap attempted to get higher yields from this variety by grafting it on C. liberica. This was done on a fairly extensive scale on his estate about the year 1900, but we may assume that no striking success was obtained, for no more has been heard of it.

Its low productivity is well known in Brasil. It was started in an experiment with various varieties in Campinas, where, out of 6 varieties the maragogipe yielded less than any other, proved to be a later ripening variety, but that the seeds were larger (J. E. T. Mendes, 1939, p. 36). The causes of the low productivity were studied by Carvalho (1939), who analyzed various factors influencing the yield, comparing them with the same factors in typical C. arabica. Several factors such as the primary and secondary branching habit, the percentage of leaf axils carrying flower buds, and so on, were examined. There was a large difference in the total number of flowers per axil but not in percentage of fruit setting.

A kind of coffee called Café Herlin, sometimes planted in New Caledonia, resembles maragogipe according to the description, but it was said to be fairly productive (Chevalier, 1931, p. 176).

C. arabica var. columnaris Ottolander (Cramer, 1913, p. 262) is characterized mainly by a more vigorous and higher growth than typical C. arabica. Old trees keep their lower branches and have about the same radius at the top as at the bottom so that the whole tree has the form of a column (photograph, p. 264). The branches bend and have a dense foliage. Ramification is also dense. Leaves are broad, large at the base of the branch, then decreasing in size in proportion to the distance from the base. The color is lighter green than typical C. arabica, and the flowers occur in small numbers in leaf axils, but are slightly larger. Berries are larger than those of Arabica, and smaller and rounder than those of maragogipe. A small sample of seed from the mother tree contained only flat beans, 93 per cent calculated on berries and 7 per cent were empty beans.

The original tree was found on Pantjoer Estate, east Java, by Ottolander, the manager. In 1898/99 it was multiplied by seed and grafts, and among the seedlings were ordinary C. arabica types. Ottolander attributed this circumstance to impurities in the seed. The young planting, laid out from seed from the first, is not absolutely homogenous; but since the planting from which the seed were taken contained trees of typical C. arabica, seed from these trees may have been mixed with the columnaris seed. A small test planting at Bangelan contained only trees that were true to type.

The yields were favorable. The number of flowers per leaf axil was small as in maragogipe, but in columnaris this disadvantage was compensated for by the larger number of branches. The variety suffered less from leaf disease. The growth was quicker than that of typical C. arabica. In Java the variety never attracted much attention. When it appeared C. arabica was already being supplanted by C. robusta, and on the arabian estates other varieties seemed to be more promising. Columnaris turned out to be of value in another coffee producing country, Puerto Rico. It was planted there as an experiment in 1931 next to the Puerto Rican or West Indian variety. In the first crop year, 1934, there was no difference in yield, but the columnaris trees were described as considerably taller and more robust and with slightly larger leaves. It also proved resistant to root rot in situations where the Puerto Rican variety of C. arabica was severely affected (Report, 1935, p. 22). In later years it surpassed the West Indian variety in yield annually, and for five years (1934-38 the total yield per acre was 5.746 lbs./acre, nearly double the yield of the Puerto Rican variety, 2.894 lbs./acre). In 1937 and in 1938 the percentage of flowers setting and of fruits maturing was higher in the West Indian variety (1938, 55.62 and 51.58) than in columnaris (1938, 35.37 and 29.47), while the latter outyielded the former by 36 per cent (Report, 1939, p. 27), thus indicating that columnaris apparently bore more flowers.

TESTING FORMS

Variety experiments with several forms of C. arabica were started in the beginning at Bangelan, where in 1901 a field was laid out with the following forms: various varieties of arabian coffee from the Economic Garden in Buitenzorg, and of special interest were the "small bean Mokka" and the "large bean Mokka". The first group gave about 2 q./ha. in 1905, the large beaned Mokka slightly more, while the other varieties produced insignificant crops (Jaarboek, 1905, p. 129). In later years various varieties were introduced again from Pantjoer Estate, but no more figures are given on the re-

sults (Jaarboek, 1906, p. 323).

The Mayagüez Station in Puerto Rico, published figures on small experimental plantings of various kinds of coffee in 1924, varieties of Arabica as well as of some other species such as C. liberica, C. excelsa, C. dewevrei, and a few hybrids. Data were given on size of beans, weight of cherries required per unit of cleaned beans, or the proportional figure, and ripening season of the crop. The C. arabicas were of special interest since they included some well defined varieties such as San Ramón, maragogipe, mocha, columnaris, erecta, and, in addition, next to "Puerto Rican Arabica", some introduced forms such as "Bourbon" and "Padang". The proportional figure was most favorable for San Ramón (5.1:1) and highest for Padang (6.6:1). For the other forms it was between these extremes. In size of bean maragogipe led with 236 g. for 1,000 beans. Most of the other types ranged between 140 and 147 g. San Ramón was 120 g., Mocha 78 g.

The yield figures expressed in liters of berries per tree showed great variations for successive years. The averages were calculated for 9 to 12 years. For the best group of C. arabicas they were 2 to 3 liters per tree per year, for maragogipe 1.6 liters, for the small leaved forms much lower: San Ramón, 0.9 to the liter; mocha, 1.1, liter; murta, 1.1, liter. The results were discussed further, and there was advice on planting certain forms in Puerto Rico. Columnaris was recommended on account of its vigorous growth, fair productivity, relatively large bean, and cup flavor. It appeared to blossom and ripen later in the season than the typical C. arabica, and it also came into bearing somewhat later. Maragogipe was not on the approved list because of its low production. Its ripening season was almost as late as that of columnaris.

Among the small leaved varieties, San Ramón was recommended for a second trial in exposed situations where the typical C. arabica did not do so well. It came into bearing at a very early stage. It was a late season variety with a long bearing season. The yield per tree was small, but owing to its dwarf, stocky form, trees could be set much closer than trees of typical C. arabica, some 4 or 5 by 6 feet apart. The smaller size of the bean was a disadvantage. (McClelland, 1924, p. 6-27 with good illustrations).

Another such experiment was started in 1931/32 in Campinas, Brazil, with plots of 5 x 50 plants of each of the following kinds: "Café Nacional, Café Amarelo de Botucatu, Café Bourbon, Café Bourbon Amarelo, Café Sumatra, and Café Maragogipe". In the publication some other tests with varieties were mentioned. The one planted in 1932 produced a small initial crop in 1934 which was not taken into account. For the following years complete particulars about the yield, the distribution of the crop over the successive harvestings, and the size of the bean were given. Bourbon and Bourbon Amarelo regularly out-yielded the others, and there was no significant difference between these two. Sumatra came immediately after them. Then came Nacional and Amarelo de Botucatu, between which there was no significant difference. The average yield of Maragogipe was considerably less, especially for the first 3 years of production, but it went up distinctly in the fourth year. It gave the largest beans and always ripened later than the other forms (Mendes, 1939).

The main variety grown in Brazil is apparently the Café Nacional, a form of C. arabica L. introduced there about 1860. Many other types were introduced later or traced in Brazil where they originated by mutations or natural hybridization. Since 1932 all this material was classified, enriched by new forms found on estates, and used for making a living collection of forms and a herbarium. It contained C. arabica var. typica Cramer, C. arabica L. var. bourbon (B. Rodr.) Choussy, C. arabica L. var. maragogipe Froehner, and a yellow fruited form of each of these three (Mendes & Krug 1938, p. 9). There were also the main varieties described by Cramer as having little economic importance. A last group comprised 6 new varieties collected in the country. Some of the latter may be of value for practical planting, and are varieties anomala, calycanthera, cera, nana, semperflorans and tetramera (p.8).

Various species of coffee have also been represented in the collections. There were 10 species listed in all (loc. cit., p. 10).

The institute at Campinas embarked on a broad program for studying the genetic constitution of Arabica and for improving it. This latter task can be divided into two parts: (a) the segregation of improved lines, and (b) the synthesis of new genetical "architectures" of commercial value. The reactions of the material under different ecological conditions are also being studied. About a thousand mother trees of the principal commercial varieties have been selected and their progeny studied in three different regions (Mendes & Krug, 1938, p. 14).

A variety test in the experiment station at Mulungu, Belgian Congo, comprised the various local and introduced forms of Arabica. In the first test the Guatemala selection was regularly the most productive. In another field, also used for an experiment on shade, two local varieties, "Kabare" and "Mibirizi", gave the best yields in the shadeless plots. In the shaded plots "Jackson" and "Blue Mountain Kenya" gave the best yields (I.N.E.A.C., 1939, p. 179).

CHAPTER 16
IMPROVEMENT OF ARABICA COFFEE

INDIVIDUAL YIELDS

In several countries where arabica is the principal species of coffee grown, a serious effort has been made to produce improved strains by starting individual tree production records in order to select the trees with the highest average yield over a given period of years. Ansted (1921, p. 338) started this type of study. The first census was made in 1919-20, a second in 1920-21. In the latter year 10.2 per cent of the trees produced 47.5 per cent of the crop. Of 77 trees which yielded less than the average of 300 berries in 1919-20, 18 were removed, having died or been badly broken. Of the 59 left, 43 again gave less than the average. Ansted concluded that a coffee bush which had fallen below a certain standard of vigor and yield remained a bad bearer if nothing was done to it. It would never bear until rejuvenated, and then there was the question of whether or not the soil, moisture, and plant food might be better distributed, to be taken from the poor trees and given to the good ones. It was evident that some 70 per cent of the trees in this case should be replaced by better bearers. Had they all been removed, the crop would only have been reduced by 31 per cent.

At the Moshi Experiment Station in Tanganyika, Gilbert (1938, p. 131) determined the individual yields of about 500 trees for a period of 4 cropping years with three objectives: (1) to build up data for an understanding of biennial bearing; (2) to enable uniformity trials to be conducted for a correct technique experiments; and (3) to obtain selections of desirable trees. The trees used belonged to *C. arabica* var. *bourbon* planted in 1929 with a few Kents as supplies. He obtained the average yield per tree for all the years. The annual coefficient of variation ranged for the 4 years between 62.0 and 169.5 per cent. Graphs for the course of the yields during the 4 years for each individual tree are included in the article. The majority of trees were "in step" (loc. cit., p. 139).

In another article Gilbert (1939, p. 249) described a method of tracing high yielding trees suitable as starting points for selection. In some 30 blocks spread over a number of coffee districts, individual tree yields were recorded, involving about 20,000 trees. The periodicity of yield appeared to be very irregular. Although biennial bearing was most common, occasional neighboring trees were out of step in this habit. Some of the trees showed little variation in the annual yield for a 4 year period, and they were considered preferable. An instance was cited of a tree (L 1, Table III) which yielded for each of 3 consecutive years more than 6 kg. of berries annually and in a fourth year between 3 and 6 kg., equivalent to a mean yield of 24 cwt. per acre or about 30 q./ha. In 1937 the yield was 12.75 kg., (Table IV). Attention also was given to characteristics other than yield, and the "field characters" of the tree such as the form of branching were noted. In Table III was given the behavior of the 55 best potential selections to date, classed into three groups: the 9 regular bearers; the 43 irregular bearers; and 3 trees selected for bean weight. It was estimated that owing to the irregularity in yielding periodicity, at least 6 years records would be necessary for definite selection (loc. cit., p. 249).

In Brazil a serious effort is being made at present to improve the planting material of *C. arabica*, especially of the Bourbon variety. It is in the hands of able research workers such as Mendes, Krug, Brieger, and Carvalho who have already published excellent studies on the variability and cytology of *C. arabica*. The Campinas Institute has started the search for improved lines of the principal commercial varieties of the country. About a thousand mother trees have been selected, and their progeny is being tested in three regions. It may be seen from graphs that the progeny show marked differences in yield and different reactions in the different stations in the first years of their production. Hybrids have also been made by crossing varieties of *C. arabica*, of Mokka x Maragogipe, of Nacional x Laurina, and certain others. The preliminary results are encouraging. Many of these hybrids have given better yields than the offspring of the autogamated parents. Some types, principally the variety *C. arabica* var. *maragogipe*, show a high resistance to dieback. Attention has also been given to the problem of obtaining forms which offer increased resistance to the berry borer, *Stephanoderes hampei*, by selecting lines with a flowering concentrated into a short period (Mendes & Krug, 1938, p. 15).

In another report (Instituto Agronomico do Estado de Sao Paulo, 1941) further progress of the research in selection was described: individual tree yields were taken for a period of 7 years with average annual crop of nearly 10 q./ha. Great variations were found, some trees being poor yielders, others capricious yielders. Some trees also gave fruit during the whole period and did not show great variation in production from one year to the next. Large quantities of statistical data were brought together. On the basis of these data the selection of the more productive and most promising plants was done with consideration of (1) their annual production, (2) their total production, and (3) their annual cycle. In various years series of mother trees were selected and their offspring

studied.

In the *C. arabica* region of the Congo the local experiment station at Mulungu, Tshibinda, was started with line selections of *C. arabica* (Stoffels, 1936, p. 40). A number of such types as "Blue Mountain Jamaica", "Blue Mountain Kenya", "Mysore", "Local Bronze", "Bourbon Ordinaire", "Mayaguez", "Guatemala", and "Santiago" were used and varieties such as "Jackson's", "Kent's", and "Pascoamah" that had previously been introduced. Some local varieties as "Kabare", "Kissegnies", and "Mibirizi", were also included and there was even a small leaved variety, "San Ramon Miniatura". A table (p. 39) contained figures for the proportion of fresh berries to market coffee for the various forms. The figure 4.83 was lowest for San Ramon Miniatura. Of the others, Jackson's under shade was next lowest, 5.36, Mysore without shade was highest, 6.83. A number of mother trees from all these varieties were chosen and used for a seedling experiment. Characteristics such as "Bronze tip" were found absolutely hereditary with the introduced varieties. In comparing the seedlings of each progeny in the nursery the morphological characteristics of the leaves, stems, and internodes were found to be perfectly homogenous. The lines of the same variety showed great resemblance. The morphological differences between the lines of the various varieties were striking. The same was found for the local varieties, but there the "bronze tip" characteristic showed segregation (Stoffels, 1936, p. 40).

SPECIAL STRAINS

When *C. arabica* was still the principal kind of coffee grown in Indonesia, Cramer (1913) studied its variability and described several variations and types with a view to choosing mother trees as seed bearers for the production of improved seed. It has been said that the individual differences are less pronounced in *C. arabica* than in *C. robusta* (Zimmermann, 1928, p. 46), but I obtained data that showed that trees of different value could be traced in a planting of *C. arabica*, and the later work at the Balehonnur Station in India further confirmed this finding. I also pointed out, not only several well defined varieties, already enumerated, but also included forms closely allied to some of these. All this material might have formed a good starting point for selection, but at the time when the basic work was done, from 1907 to 1909, Robusta began to absorb most of the attention of the research workers and planters.

Not until about a decade later was a new start made with the breeding of improved forms of *C. arabica* and of hybrids with this species when Schweizer started his work on the subject. Most of the material studied by me had long since disappeared. Of the older *C. arabica* varieties Schweizer thought of using columnaris, not highly productive of itself, but showing vigorous growth, as a stock for grafting. Seedlings were raised from a tree from Pantjoer said to belong to this variety; but it is doubtful whether it belonged to the genuine variety, and when the seedlings did not show a marked difference from ordinary *C. arabica*, the experiment was stopped. In other directions remarkable progress was obtained. Planters of arabian coffee kept an open eye for superior trees of the species, and this led to two interesting finds, the Hemileia rust resistant arabian coffee of southern India, discovered and developed by Kent, and Kissing's high yielding Pascoamah Arabica. Cramer contributed a third variety, the Abyssinian Arabica sent by him to Java in 1928.

Kent's Arabica, sometimes called a hybrid, is a variety in the same sense as Pascoamah. It was discovered by L. R. Kent, a planter of the Doddengudda Estate in Mysore, as a Hemileia resistant tree (Anon., 1933, p. 84). The description of the origin by Marggraff (1934, p. 991) is slightly different. Kent isolated the tree under mosquito gauze during the flowering, raised about 2,000 seedlings from these isolated seed and took 16 of them as representing the pure type. By continuing in this way, the percentage of the pure type was increased in the fifth generation to 90 per cent. At Balehonnur, in southern India, it proved resistant even against artificial infection with rust. Two types were introduced into Indonesia. Both showed leaf disease; the second somewhat less than the first. Al Kalisat on the Idjen plain, a planting in an experimental field showed more resistant leaves than Pantjoer Arabica Hybrids. The berries of Kent's coffee were found to be smaller and rounder (Anonymous, 1933, p. 62).

At Bangelan in Indonesia, Kent's coffee also proved more resistant (Marggraff, 1934, p. 992). At Toeloengredjo in east Java at an elevation of 1,200 m., a small testing plot produced well. That is in the fifth year it produced 4.5 q./ha, in the sixth year, 10 q./ha. (Marggraff, 1935, p. 170). In the Cultuurtuin at Buitenzorg one of two sets of plants did fairly well, but when last seen it was still too young for a final judgment, and its production was too insignificant to present any commercial possibility under conditions there.

Kent's Arabica seems to have developed another variety, Kent's with "chick" habit, which was with upright branches. In Kenya it had given satisfactory results when grown in the drier belt at low altitudes (McDonald, 1937, p. 61). Apparently this variety was an erecta form of Kent's Arabica.

At one time there were rumours in Indonesia about the degeneration of *C. arabica* in Brazil.

There had also been proposals to introduce the so-called Kent Arabica from southern India to Brazil (Marggraff, 1938, p. 348).

A variety of arabica frequently mentioned in connection with Kent's and also of southern Indian origin is the so-called "Jackson Hybrid". It was introduced at Soember Asin by the Malang Research Institute, in Indonesia, but it was not a success (Hille Ris Lambers, 1931a, p. 687). In a variety test at the Mulungu Station in Africa it did very well (I.N.E.A.C., 1939, p. 179).

According to Du Pasquier (1928, p. 49) it was obtained by Anstead as the result of a double crossing, arabica x liberica x arabica. This F₂ hybrid can be multiplied by seed. It is vigorous and high yielding, resistant to the borer (Xylotrechus) and gives a market bean which is the qualitative equal of C. arabica. However, it was very susceptible to leaf disease. Coleman (1934, p. 311) mentioned the Jackson Arabica as a selection of the typical C. arabica type and noted that it had not lived up to its early promise and had practically disappeared from cultivation, in contrast with the Kent Arabica. Curiously, in Peradeniya, an arabian, apparently of the local Ceylon type, did much better during the seven year period from 1923-24 to 1929-30, than did Kent's and Jackson's hybrids. According to the Bulletin of the Imperial Institute (see Anon., 1931b, p. 198) the Jackson's type made by far the poorest showing. Stoffels (1936, p. 40) made extensive seedling experiments with varieties of C. arabica at the Mulungu-Tshibinda Station, Kivu, Belgian Congo. Among various local and introduced varieties which he used were Jackson's and Kent's. For these, 5 and 9 lines descending from one mother tree were tested. A number of seedlings in the nursery of each line were perfectly homogeneous for the morphological characteristics, and the lines belonging to the same variety resembled each other; while there were striking morphological differences between the lines of different varieties.

The Pascoemah variety of C. arabica was found on the Pascoemah in Upper Palembang by Kissing, the manager, in a field planted in 1903, as a regularly high producing, healthy tree giving 1.2 to 1.8 kg. of market coffee. The seedlings were uniform, densely branching and productive (Cramer, 1916, p. 206). This variety showed hybrid characteristics to a high degree (Frahm-Leliveld, 1938a, p. 26).

In Java two fields were planted with seedlings of C. arabica var. pascoemah on the Pantjoer Estate in 1912. The growth was so vigorous that further fields were planted in 1913 (Stibbe, 1915, p. 218). In 1915 the new variety proved much more productive than common arabian but even so did not suffer from overyielding (Cramer, 1916, p. 208). Since then the Pascoemah variety, further improved at the Besoekisch Proefstation, became a favorite variety of C. arabica under the name of "Blawan-Pascoemah" (Vraagbaak, 1941, p. 127). It was known as resistant to leaf disease and overproduction. It required more space and needed less shade than other varieties. Schweiser (1931a, p. 58) remarked that the flowering of the Pascoemah variety was less dependent on external conditions than some and noted that it gave a regular crop. Therefore it was valued highly by the planters. In the experiment at Kalisat the Blawan-Pascoemah was among the best (Anonymous, 1933, p. 62). On an estate in central Celebes a planting of seedlings of "Hava Pascoemah" at an altitude of 750 m. gave one crop of 18 q. market coffee per ha., but then the trees died (Anonymous, 1932a, p. 312).

FORMS FOR THE LOWER ARABIAN BELT

Special mention must be made of a problem facing some of the arabian estates. Since 1900 when Ottolander said that an altitude of 2,000-3,000 feet was suitable for C. arabica, the situation has changed. What may be considered now as the highland belt favorable for C. arabica begins at about 1,200 m. Mohr (1938, p. 744) described a visit to the Pantjoer Estate in 1931, where he found the fields above 1,200 all free from Hemileia rust. From 800 m. or 900 m. to 1,200 m. there was some rust but it was not noxious. However, the yield of the coffee was lower. Under 800 m. there were fields, but they were considered risky. It is curious to note how the demarcation lines for the leaf disease corresponded to types of soil: above 1,300 m. there was a pseudosand, then a belt of brown yellow mountain lixivium. Perhaps the soil played a part in making the belt from 800 m. to 1,200 m. suitable for C. arabica.

On the other hand, above 800 m. the climate was somewhat too dry and high for C. robusta which yields only half as well there as in the middle belt. Seeking a suitable type for this belt, Schweiser, of the Djember Research Institute, made hybrids of Robusta and Congusta with Arabica, breeding them further with Arabica. The crossing was done in 1923. Schweiser arrived at the F₄ generation, which contained many types closely resembling C. arabica in leaf and fruit characteristics, growth and flowering. These hybrids withstood even the climate of the coastal plains, for instance, in Kaliwining and Djember itself, only 50 to 100 m. above sea level, and they did not suffer from leaf disease as heavily as did pure C. arabica at this altitude.

These hybrids might have been the solution for the problems of the lower C. arabica belt, but an easier one was accidentally discovered. In 1928 Cramer visited coffee estates in Abyssinia, and

noting the vigorous, healthy appearance of the trees, selected some mother trees and sent the seed to Java. This introduction of Abyssinian coffee was mentioned in the annual report of the Besuki Institute for 1928 (Gandrup & Schweizer, 1931, p. 52). The first crop was obtained in 1932. It was very satisfactory and --still more important -- it did not damage the trees (Schweizer, 1933a, p. 69). In later years Abyssinian coffee gave good results in the lower growing zone. It suffered less from leaf disease there and was recommended for this zone. In an experimental field at Kalisat on the Idjen plain, it surpassed all other kinds by its very vigorous growth and high resistance to leaf disease. After the first crop, which was quite good, the trees showed no signs of overbearing; they showed a dense, dark green foliage and promised a good crop for 1933. No other one of the various kinds tested in this field gave comparable results (Anonymous, 1933, p. 62). Other varieties of C. arabica have been introduced as a result of the visits of Hille Ris Lambers and van der Veen to Africa. These kinds have been under test by the Malang and Besuki Institutes. and may bring further improvement.

It is curious to note that apparently a kind of Abyssinian coffee was introduced into Java 80 years ago. A note with a translation of the article on C. stenophylla in the Kew Bulletin of 1896 mentioned that in 1864 on Limburg Estate, near Malang, there was a planting of introduced Abyssinian coffee. The berries were very small (Stennekes, 1898, p. 620). In connection with these varieties of Abyssinian coffee there were indications that C. arabica includes several varieties in its country of origin. Tissot (1939, p. 173) describes various types with smaller and longer, narrow beans, but it is always uncertain in such cases to what extent these differences may be caused by external conditions. On the plantations managed by Europeans 2 improved strains had been developed which were resistant to leaf diseases present there, viz., Cercospora coffeicola and Hemileia vastatrix.

CHAPTER 17
COFFEE LIBERICA AND ALLIED SPECIES

CHARACTERISTICS AND ORIGIN

The true liberian coffee is a much more vigorous, coarser type of plant than the arabian. If left untopped it grows into a tree which may reach a height of 15 m. The bark is dark brown, branches are stiff and strong. The leaves are dark green and leathery, large and broad. The average length of the leaves varies around 20 cm., but leaves of 40 cm. have been found. The width is nearly a third of the length, but it is considerably more in broad leaved types. The flowers are large, somewhat fleshy, often with more than 5, up to 9, lobes. The tube is about 1.5 cm., and lobes are slightly over 2 cm. long. The time between flowering and ripe fruit is nearly a year. Characteristics of the berries show variations when different trees are compared; great uniformity for berries of the same tree. Color ranges from a wax yellow to a dark reddish brown, generally not even. The red is distributed in small points of short small lines. The skin is tough and hard, somewhat woody, with a dry, thick outer layer which generally cannot be pressed open with the fingers.

The shape is round, spherical, or oblong, pear-shaped. Size and length very a good deal even for berries of the same tree. With small fruited types the mean length is about 18 mm., with large fruited types 31 mm. and even more. The discus is quite variable in size and shape. The proportion of berries to market coffee is generally figured at 10:1, for some types just under 8:1, for the other extreme over 15:10. The thick, hard skin and the thick glucose layer make the pulping and fermenting of the pulped beans difficult. Freshly pulped coffee is brownish. The parchment skin is thick, woody, hard and brittle. Silver skin on the freshly pulped bean is dark green, and it is difficult to remove from the dried beans unless the drying has been done at a high temperature. Beans dried at a high temperature acquire a bright lemon-yellow color. Liberian coffee has an average bean weight of about 0.3 gr. and of all species of coffee it has the largest and heaviest beans.

The history of the introduction of Liberica into tropical agriculture was recorded in 1890, on page 245 in the Kew Bulletin of that year (Anonymous, 1890a). About 1872 Sir Joseph Hooker had his attention directed to a large berried coffee which grew wild in Liberia but had been introduced into cultivation on the Gold Coast and in Sierra Leone. From the latter colony 9 plants were sent to Kew in 1872, but all were dead upon arrival. About the same time 480 seeds were obtained from the Rev. T. B. Freeman, who had a small coffee plantation near Accra. Plants were raised from these seeds at Kew. In 1873 Bull imported living plants for his nurseries in Chelsea. In 1874 and 1876 larger supplies of seed were obtained at Kew directly from Liberia. The plants were distributed from Kew to tropical botanical gardens throughout the Empire. Data on the history and early cultivation of Liberian coffee in British colonies with references to the literature compiled in 1890 were in the Kew Bulletin. Details on the introduction of C. liberica into Java in 1875 are given in another part of this work.

In the beginning the reports on C. liberica were enthusiastic. The growth of the introduced plants was reported as good in 1878; and "if the product will be well received, the new coffee may be a blessing for the low country", Scheffer prophesied (Verslag, 1878, p. 29). The continuous flowering and ripening of fruit and the first crop, quite considerable for a three year old planting, are all mentioned.

There was some doubt whether Liberica really had its origin in the country for which it was named. According to an inquiry, Liberian coffee is found in Liberia proper in a cultivated state in the low coastal lands, often quite near the sea. The wild form occurred further in the interior. According to an old inquiry, the wild coffee from which the cultivated variety came, was found at distance of more than 30 miles in the interior (Anonymous, 1876, p. 1). It had been found there up to 550 feet above sea level. A distinction was made between two types, one with large and one with smaller berries. The latter entered production earlier (Ind. Mercuir, 1892, p. 581). Büttikofer (1891-92) travelled in Liberia and stated that C. liberica really grew wild in the jungle there. Aug. Chevalier (1908), however, stated in 1908 that it is found there only as a cultivated plant. This explorer thought its country of origin was Angola, where Welwitsch found two species of coffee during a visit in the middle of the eighteenth century. One of these, the later C. liberica, was described by Welwitsch as "abundant and quite certainly indigenous" to the districts of Casengo and Golungo Alto in Angola, in the forests of Mount Muxaulo. In the second region it was located in the virgin forest of the Cungulungulo at about 2,000 feet above sea level, where it grew alongside C. arabica, also considered by Welwitsch as indigenous to Angola. According to later investigations by Aug. Chevalier (1939, p. 397) this was not the case. As a spontaneous plant, C. liberica was very localized and hitherto known only from the hinterlands of Liberia and the highlands of the Ivory Coast.

The identification by Welwitsch and Hiern of Liberica in Angola was based on the erroneous description of two specimens by Welwitsch, both of which belonged, to C. canephora Pierre. One of

these specimens even typified C. canephora var. hiernii Pierre ex de Wildeman, which is similar to the C. canephora var. kouilouensis Pierre, also called C. dewildemann Pierre, often cultivated in French Gabon, the Lower Congo and Angola. Other details on the history of Liberica are contained in Burkill's excellent article on Coffea in his Dictionary (1935, p. 622). As early as the end of the eighteenth century, Afzel had collected it in Sierra Leone. Then, in 1865, Aubry Lecomte called attention to it under the name "Munrovia Coffee", and in 1870 living plants were actually brought to Paris. In 1872 Sir Joseph Hooker again directed attention to it. From Afzel's collections he knew it as a cultivated plant of the tropical lowlands of Sierra Leone and Liberia. From the small estate of one of the European settlers on the Guinea coast came the first considerable consignment of seed.

Hiern (1876, p. 172) published the first description of the species based on material in the hothouses of the British nursery firm of Bull, adding, "The name of Coffea liberica was given by Mr. W. Bull, F. L. S., of Chelsea, in order to distinguish from the common coffee of commerce, young plants which he obtained from seeds of Liberian coffee that had been sent from the west coast of Africa". The question was discussed further by Cramer (1913, p. 282). In my case, the Liberian coffee, if not indigenous in Liberia, grew very well there.

The conditions in Liberia are much the same as in the lower coffee belt in Indonesia. They were described by Wigman (1890, p. 257) in an article in which the results of an inquiry by the British government on optimum conditions in Liberia were also mentioned. Further data on the history and conditions of cultivation in Liberia were published by Netscher (1893, p. 399). According to Leprieux (1936, p. 15), C. liberica had been found by Laurent as a wild coffee in the Belgian Congo at Wanié-Rukula on the Luabala in the forest. Leprieux also gave a record of several attempts to establish plantations of Liberian coffee in the Belgian Congo.

POPULARITY AND DECLINE

In the first decade after its introduction into Java, Liberica was not very popular, but when the leaf disease proved disastrous to Arabica in the lower zones, the attention of planters turned to the new kind, and its area extended rapidly, especially in the lower regions (van Romburgh & Wigman, 1896, p. 509). It was considered the crop of the future for these regions, and it won popularity among planters when the results obtained with this species by van Motman on the Dramaga Estate became known (Netscher, 1893, p. 402). In the lower coffee belt and even at higher altitudes, up to about 700 m., especially in the wet climate of west Java, Liberian coffee was considered a promising crop. In 1891 it was reported that the area planted in C. liberica had been extended greatly. Crops of 8 to 14 piculs, per baho, or 7 to 12½ q./ha., were not rare, and the product was in much demand. The entire crops of some estates were sold to American buyers, and the price at 65 cents per half kilogram was slightly higher than that for Arabian coffee (Soekaboemische Landbouw-vereeninging, 1891, p. 10). Up to 1895 the reports continued to be very favorable, and it was reported to be free from diseases (loc. cit., 1895, p. 13).

In those days Liberian coffee was also recommended to the government plantings. In 1894 the government issued a circular laying stress on the advantages of the new kind, which was described as less exacting with respect to soil, less susceptible to leaf disease, not requiring a heavy shade, and giving a fair crop for 7 months of the year. Its vigorous development and thick leaf cover retarded the growth of weeds, and it had a longer life than Arabica thus making it unnecessary to make new openings for replacements soon after planting. Two years later, however, when prices were low, the greatest caution was recommended (Huitema, 1935, p. 33), and thus Liberian coffee never obtained an important place in the government plantings.

Its habits of nearly continuous flowering and fruiting and its suitability for a wet lowland climate, already mentioned by Bull (1897, p. 520) in a circular on the new species, prevented the total failures of crops which had been experienced in the case of C. arabica. These advantages attracted the attention of planters (Prins, 1895, p. 617). In a report on Gemampier dated October 1880 van Delden (1886, p. 327) said that C. liberica trees showed flowers, young and more advanced fruits, and ripe berries, simultaneously. An enthusiastic early report was made on this coffee in which this continuous flowering was cited (Waller, 1887, p. 249), but the difficult pulping was mentioned as a drawback. The difficulty of curing the Liberian coffee was also explained (see Liberian Coffee Anonymous, 1888a, p. 261-262).

From the beginning this difficulty gave the planters trouble and made them alert for improvements. The problem of designing satisfactory machinery for pulping the tough, thick skinned berries, of finding a practical way of fermenting the pulped beans and obtaining beans free from silverskin, was not easily solved. Complaints about these points were frequent in the planters' press at the time (Indische Mercur, 1893, p. 327 and p. 418); and when the first hybrids with Arabica were discovered, their advantage of producing juicier fruits, easier to pulp, was generally emphasized.

By patient experimentation with various methods of curing and by trying various designs of

pulpers, the planters were able to overcome the difficulties presented by C. liberica. There was a time when it was hoped that this new kind would help to restore the great old days of highly profitable Arabica coffee production. From the very beginning, however, there was one drawback; even perfectly cured Liberica did not possess the excellent aroma of arabian, and although a sample of well cured liberian, with its large, lemon yellow beans, looked attractive enough, the market would not pay the same price it would pay for the finely flavored arabian. Brokers estimated samples for appearance at 32 to 33 cts., and for flavor at 20 cts. in March 1885 (Wigman, 1888, p. 10).

In the beginning its curing caused many difficulties. Beans prepared by the dry method had a bad taste, but when the wet method was applied and skins and pulp were quickly removed, the brokers' opinion was favorable (van Delden, 1886, p. 347). In 1896 the larger planters' organization in west Java, the Soekaboemische Landbouw Vereeniging, published the following statement in its annual report: "In west Java liberian coffee has taken the place of arabian coffee almost completely. There is a strong likelihood that as a consequence, this part of our beautiful island will reach the same degree of prosperity it enjoyed during the flourishing period of Arabian coffee".

In 1903, which was 7 years after this optimistic report, the same organization declared that this hope had not been fulfilled. In contrast most of the estates had abandoned the production of liberian coffee and had converted a large part of the plantings into tea or Cinchona. In 1903 the liberian crop remained far under the estimates, and the prices, from f 18 to f 23 per piculs, were lower than ever (Anonymous, 1904, p. 138). At a planters' conference in Malang in October 1903 liberian was considered suitable for replanting old arabian coffee fields. The average yield was estimated at 4.5 q./ha., the market price at f 23 at the report of export. At this it could still produce a small profit (Kluvers 1903, p. 568).

The possibilities of replanting old arabian fields with liberian coffee were discussed by Leijssius (1901, p. 496), who cited the success obtained with an experimental replanting then 5 years old. Other planters mentioned similar cases, among which there were reopenings on nematode infested fields. If, notwithstanding its greater resistance, C. liberica lost its popularity, the low price it fetched was probably one of the main causes. Some years earlier it still fetched about the same market price as arabian, about f 60 per picul (ibid., p. 141), but the change set in during 1897. In the beginning of 1898 one of the planters complained that with the fall in the market prices the golden days of liberian seemed to be over (Soekaboemische Landbouwvereeniging 1898, p. 252). In 1899 the cost of producing a normal crop of 700-750 kg. per hectare was calculated at f 26.50 to 27.50 per picul before it reached the port of export (Anonymous, 1899, p. 4). Thus the situation had deteriorated gravely.

The decline of production resulting from the increasing virulence of leaf rust disease also most certainly contributed to this disillusionment. The frequent voice urging the application of rational selection to prevent the so-called degeneration of this coffee had no effect, although the species would certainly have lent itself very well to improvement by seed selection.

VARIABILITY

From the very beginning a great deal of individual variation had been observed in Liberian coffee, but well defined varieties such as those found in the arabian, such as rod leaved, narrow leaved, erectas, etc., are not known in the liberians. The great individual variability in the trees introduced at first has been described. Among these there were four distinct forms which could be distinguished, and for some of these still another, one with round berries and one with oblong berries were identified (Jaarverslag, 1877, p. 28). Similar variations were observed in plants introduced into Ceylon or grown there from introduced seed (Thurber, 1881, p. 115).

In Java, the first generation of seedlings of the introduced trees, showed the same great variability as the introduced trees (Kievits, 1891, p. 92-3). Since then it was always characteristic of the species (Kramers, 1898, p. 51). On the other hand, material from trees in Liberia itself, received from Soeters, a Java planter who went there in March 1908 to collect seed for a new introduction of the species into Java, allowed a study of the variability of liberian coffee from Liberia itself. It was found to be similar to that of later generations in Java (Cramer, 1908e, p. 66-67, and Jaarboek, 1908, p. 85).

The only variation which C. liberica had in common with the trees of C. arabica and C. robusta was the occurrence of trees with virescent flowers. A clone with this abnormality was included in the collection of the Besuki Institute at Djember. The heredity of star-flowering in three C. liberica types could be proved by comparison of the clone and its legitimate seedlings (Gandrup & Schweizer 1931, p. 53).

IMPROVEMENT OF PLANTING MATERIAL

It is understandable that this great variability in morphological and practical characteristics

and, moreover, in resistance to Hemileia disease, invited selection of the species. This resistance, greatly varying for the individual trees, the alleged degeneration which was actually caused by the increased virulence of Hemileia and the desire of the planters to introduce "new blood" into the species planted in Java, already has been discussed somewhat. Frequent opinions were heard insisting on the initiation of selection and drawing attention to the variations in morphological characteristics. A writer on the subject made the quite logical remark that where these individual characteristics were so different for various trees it could be possible that the flavor of the product would also show individual variations. Curiously enough, this fact was later confirmed for robustoid clones (Ind. Mercur, 1898, p. 552).

In 1905 the Djember Planters' Association discussed improvement. Again the great variability of the species in Java was emphasized (p. 568), and means for fixing the desirable types were considered (Anon., 1905, p. 561). In 1907 a Committee of planters was set up to consider the matter in collaboration with Cramer. A note on the selection of seed, especially by selecting mother trees according to the characteristics of their progeny, was published (Liberia en Robusta-bibitcommissie, Anon. 1907c, p. 197, Point 5), and a special plot for the selection of *C. liberica* was started (Treub, 1906). Several individual offspring from superior trees were planted here. The seed had been taken from trees isolated by tents put over them to prevent cross pollination.

They gave plants which were comparatively Hemileia-resistant in the nursery. When these plantings were 18 months old, all were reported to show "without any exception" signs of deterioration, and after some months the fields had the same appearance as every planting of *C. liberica* from mixed seed (Jaarboek, 1909, p. 177). There is some doubt that the material was as bad as described, for van Helten (1915, p. 7) made grafts of some of the best types. In a later report (van Hall & van Helten, 1917, p. 44) six were mentioned as grafted. In the case of H.1 the growth was good and leaf disease only slight. In the case of J.1 two of the grafts were very good and free from leaf disease. Both clones were kept in the Cultuurtuin and showed a good foliage, free from leaf disease, and a good yield, but with H.1 the berries were attacked by Hemileia.

Meanwhile planters had also begun the selection of *C. liberica*. At Gemampir Estate, near Klaten, planting was done from the very beginning with the offspring of trees of a well defined type, and after several generations a more uniform type seems to have been obtained, with a softer berry and a good market product (Kramers, 1899, p. 80). According to the same author there had been a gradual change in liberian coffee from the Cultuurtuin. The berries became softer. The change took place mainly between the second and third generation. The fourth and fifth generations were similar to the third. The softer berries ripened quicker and were easier to pulp (Kramers, 1898, p. 51).

In west Java, the Pondok Gedeh plantations began production of improved seed. At first an attempt was made to establish an isolated seed production field in an opening in the jungle, but the trees did not grow well and another way was tried. On four divisions 100 superior trees were chosen. All small and older fruit were removed, and the trees were enclosed in a sort of a tent as soon as they flowered in order to isolate the flowers (Anonymous, 1905, p. 47). In some cases two neighboring trees, both superior specimens, were enclosed in one tent for cross pollination. The trees suffered a good deal from the hot, moist atmosphere under the tent (J.C. Valetta, 1905, p. 935). On several occasions a census was taken of the occurrence of leaf disease, and trees suffering badly from it were rejected as seed bearers. Morphological characteristics, for instance, and the angle of the branching, were also recorded. It was found that trees with sharp angles were the poorest ones.

The seed obtained from the trees was used for new fields. Bangelan received seed from one or more superior trees in these fields and used the seedlings for laying out Field 144, which for many years gave very good yields, equal to or better than the old liberian had given before "degeneration" set in. In 1920-1924 the field gave over 10 q./ha. annually, with 578 kg. and 1,591 kg. as extremes, a yield which compared favorably with that of a planting considered to be a very good one in the eighties, for which an average of 834 kg. per ha. over the period 1886-1889 was recorded, with 510 kg. and 1,030 kg. as extremes (see Cramer, 1927, p. 139). Baud (1894, p. 305) was conservative and estimated the average yield of *Liberica* at that time as 7 piculs per bahoe (6.3 q./ha.). Figures from others compare favorably with the old ones, and even with those for Dutch Guiana, a country where optimum conditions and no leaf disease existed. There a yield of 19 q./ha. was considered top production (Cramer, 1918, 1919, p. 25), and a crop of 18 q./ha. in 1929 was called phenomenal (Anonymous, 1927, p. 93).

In the Cultuurtuin a few clones were made from the original trees on Pondok Gedeh Plantations. It is curious to compare their stand with the data for the mother trees. It was found that PP.67, a fairly Hemileia-resistant tree but with sharp angled branches, gave an excellent clone, one of the healthiest and most beautiful ever observed, while PP.21, superior as mother tree, was not so outstanding as a clone. The Cultuurtuin also laid out a seedling planting from PP.67, where, although most of the trees suffered from leaf disease, they had a better appearance and less rust than other

plantings of C. liberica seedlings from disease-resistant trees (van Hall & van Helten, 1917, p. 42).

At present liberian coffee has completely lost favor with coffee producers in Indonesia, and there is probably no new planting of it. If the species were to be adopted again by the industry, the present material in the Cultuurtuin and at Bangelan could still help the estates improve seed, from which better plantings than the old ones might be expected.

CLOSELY ALLIED SPECIES

C. liberica Bull forms one group with C. arnoldiana de Wild., C. abeokutae Cramer, etc. A whole series of species and intermediate forms have been found in Cameroon and the Oubangui-Chari provinces of west Africa, and these constitute a transition between the latter group and C. excelsa Aug. Chevalier (Portères, 1936, p. 48).

Many of the allied species have been introduced into Java by the Plant Breeding Station and so far as known are still kept in the Cultuurtuin. All had smaller berries than C. liberica and generally showed stronger resistance to Hemileia. Only one, C. excelsa, had acquired sufficient economic importance for commercial quantities to be exported.

Of these allied species, C. aruwimiensis, from the Belgian Congo, was most closely related to C. liberica. The berry is smaller, ablong, and of the same color as in Liberica and has a rough, dry skin. The leaves are narrower, more supple, and of a lighter green, and they are only slightly susceptible to Hemileia. The flowers have 5 or 6 lobes, while there are often more in Liberica.

C. dewevrei has been under study at Kaliwining the Djember Institute, as a possible stock for grafting, since a set of seedlings on a nematode-infested spot developed well. There was, however, some difficulty in grafting Robusta clones on it. This species could be described as a small berried liberian coffee. The glucose layer was juicier, and the thick skin of the fruit was softer than in the main species. The same description applied to C. arnoldiana, which was also indigenous in the Belgian Congo, and it too was represented in the Cultuurtuin by one clone. It resembled C. dewevrei so much that one would hardly consider it as belonging to another species. Only the flowers while in bud a day before opening, showed a faint hue of pink, a fact that would indicate a relationship with the next kind to be discussed. It was received from the Serres Coloniales in Laeken in 1907, and the introduction was repeated in 1915. The latter set of plants gave better results than the former (van Hall & van Helten, 1917, p. 9).

A well defined species seemed to be C. abeokutae, introduced into Java through Kew Gardens, from Abeokuta in 1898 (Verslag, 1898, p. 27) and described by Cramer (1913, p. 395), who considered the species promising and recommended its conclusion in experiments with new kinds of coffee. The planting of 63 trees in the Cultuurtuin yielded at a rate of 9.6 q./ha. in 1908, and for some trees the yields were very high, 3.5 to 4 kg. of market coffee per tree (Cramer, 1913, p. 419). Some figures for individual yields in 1914-1916 can be found in van Hall & van Helten (1917, p. 14). Each of these years three numbers produced good yields, viz., 179/01 averaged 2.4 kg.; 179/13 gave 3.1 kg. and 179/04 gave 3.0 kg. A drawback noted was that Abeokuta coffee came into production late. The quality of the product was considered equal to that of arabian by an expert (Cramer, 1913, p. 416). Further advantages were high resistance to Hemileia and a soft skinned berry easier to pulp than that of liberian. It also had a slightly better proportion of about 8.7:1.

In an infection experiment Cramer (1913, p. 424) found seedlings not susceptible to Teylenchus coffeae. Among the botanical characteristics of C. abeokutae in comparison with C. liberica, were noted the lighter green of the foliage, the more flexible branches, and the smaller berry of a brighter red color due to fine stripes of yellow on the red ground color. A very striking characteristic was the pink color of the flower, which in a dry climate often had a delicate pink tint of apple blossom. In the period 1907-1909 seed was distributed in Java, but none of the estates where the new kind was tried actually extended cultivation with it. Apparently it could not keep pace with the rapidly growing popularity of Robusta.

A few clones from the originally imported trees and from a couple of trees of the first generation, some of which contain liberian strains, are possibly still kept in the Cultuurtuin. In other coffee producing countries Abeokuta coffee became popular. On the Ivory Coast of coffee is grown under the name "Gros Indénié", a variety of Lagos coffee the C. abeokuta Cramer. It was first distributed as "Improved Liberica". In 1928 Castelli started selection with the "Gros Indénié". "As-sikasso No. 19" is now a strain popular on account of its vigor, high productivity, and small bean. Another descendant of this No. 19 gave a product of good quality which would please the taste of the French consumer and probably obtain a premium over the Robusta price (Rochette, 1935, p. 36).

When commercial quantities of the "Indénié" or "Gros Indénié" which are a kind of Abeokuta coffee, sometimes became available, small beaned liberian was mixed with it. This mixing affected the taste, which in real "Indénié" is superior to that of liberian. There was a marked difference in taste between the two kinds. "Its taste characteristics are very different from those of the

Liberia coffee" (Portéres, 1938, p. 163). Sibert (1932, 94p.) mentioned a form of C. liberica with smaller fruits indigenous in the dense forests of the Ivory Coast called C. liberica var. ivorensis, and another form, C. liberica var. indeniensis, with smaller fruit than true C. liberica and giving a market product that enjoyed a higher degree of appreciation. These data are interesting since they reveal the greater appreciation of the product of Abeokuta coffee.

In Ceylon, Abeokuta gave good results. In an experiment at Peradeniya, Abeokuta coffee did better than, either C. excelsa or C. liberica (Anon., 1931b, p. 198).

COFFEA EXCELSA AND ALLIED SPECIES

Another group of liberoid species is headed by Coffea excelsa. This species was discovered in January 1903 by Aug. Chevalier in the gallery forests in the valley of the Boro, a small river tributary of the Bake Tete, a branch of the East Upper Chari the Senoussi Territory, Central Africa, at an altitude of 500-800 m. Here the annual rainfall is 1 to 1½ m., with a 6 months dry season. It was seen there on soils composed of sand with 3 to 4½ per cent clay (Chevalier, 1905, p. 517, 1926, p. 672).

The new species was introduced into Java by the Department of Agriculture in 1905 and several times subsequently (Cramer, 1916a, p. 211). Besides the seed obtained by the Department of Agriculture, private estates also introduced material, probably all from the well known nursery firm of Vilmorin Andrieux in Paris (Cramer, 1916a, p. 213). This firm obtained the seed from Chevalier himself. All the C. excelsa introduced into agriculture comes from the one locality in the valley of the Boro (Chevalier, 1926, p. 671). A preliminary description was published by Chevalier in 1903, followed by a full description in 1905.

Excelsa grows as a small tree from 8 to 20 m. high in the jungle. It resembles liberian coffee with its tall growth and broad, dark green leaves. Great variations occur in the size, shape, and texture. Some of the introduced trees in the Cultuurtuin had flat, coriaceous, very dark green leaves, but in other trees they were more supple. The domatia were less developed than those of C. liberica, sometimes entirely absent (Cramer 1913, p. 669). Leaves were found of over a half a meter in length. The berries were very different from those of C. liberica, much smaller and shorter. They were generally as broad or even broader than long, of an even or very faintly striped carmine red color, attached in thick clusters to the branches, sometimes even on the stem (Cramer 1916a, p. 213). Nodes carrying ripe fruit might also show flowers. The same node could bear fruit year after year. After the flowering and during the growth of the young berries the vegetation points of C. excelsa did not perish, as they do in C. ugandae and C. robusta, but retained their vitality (van der Meulen 1939, p. 1-127).

The berries were soft and juicy, and could be pressed open with the fingers (Cramer 1908, p. 601). Fruit size varied a good deal for the various trees. Form and size of the discus are also variable. In the drawing published by Chevalier (1926, p. 673) the berries were oblong, and on the trees grown from seed introduced into Java they were generally broader than long. The flowers of the wild trees were always five-lobed (p. 670).

The parchment skin was brownish. The proportion of berries to market coffee varied between 6 and 7.5:1. The pulping and further curing was as easy as it was with robustas, except that in C. excelsa the berries varied more in size. In some trees the percentage of round beans was high (Cramer 1916, p. 221). The silverskin loosened with difficulty from the bean, just as in all liberoid coffees. The finished market product looks like small beaned liberian coffee. According to Chevalier (1903, p. 38) the taste resembled that of Harrar Arabica.

Excelsa proved to be susceptible to Homileia shortly after its introduction into Java. In one of the first notes on the young plants in Java the occurrence of the rust on the leaves of 5 months old plants was recorded by Treub (cited by the Malangsche Landbouwwerenging, 1907, p. 135). The young planting of trees raised from introduced seed had a bad attack of leaf disease in February 1906. Most of the trees recovered, but those which were the first to flower remained diseased. C. excelsa was also reported as very susceptible to Corticium (Cramer 1913, p. 677).

In other countries C. excelsa has shown an easy adaptation to varying conditions and a high resistance to adverse factors. In Tonkin it was more resistant to the borer (Iylotherechus quadripes) and withstood the climate better, giving higher yields than Arabica (Chevalier 1929a, p. 24). In the test plot at Rio Claro in Brazil, Edm. Navarro de Andrade found that it was resistant to frost. Not a single leaf or berry was damaged, while varieties of C. arabica, C. dybowski and C. abeokutae suffered from frost (Chevalier 1929a, p. 25). At the St. Clair Experiment Station in Trinidad, C. excelsa did much better than C. robusta, and in 1916-1918 there was some demand for planting material (Wester 1920, p. 368). Virescence or "sterretjesbloei" was observed in west Africa; in Java a C. excelsa gave 25 per cent, but not in C. excelsa from the Chari region, from Annam, or from Kisantu in the Belgian Congo (Portéres, 1939).

Returning again to Indonesia, at Bangelan several fields had been planted with seedlings from C. excelsa trees introduced in 1909, among which especially Hemileia-resistant ones were selected. In 1915, after the exceptionally dry year of 1914, they gave yields which could be considered quite satisfactory for the sixth year, varying from 3.5 to 9.5 q./ha. (Cramer 1916a, p. 217). A good offspring was obtained from the mother Excelsa Bgn.121, and several new mother trees were chosen from among these seedlings and used for further planting, i.e. Excelsas Bgn.121.07, 121.09, 121.13, etc. Five fields of these plantings gave 19 to 61 per cent more than average Robusta, taken over a period of 13 to 17 years (Ferwerda 1935, p. 1, table 1).

Huitema (1935, p. 179) gave a good summary of the pros and cons of C. excelsa. He stated that at Bangelan, C. excelsa that was 5 to 12 years old, yielded 1,100 kg. market coffee per ha. in 1921-1929, while similar C. robusta plantings averaged 1,050 kg./ha. The product resembled a liberian, and when properly cured it had the same bright lemon yellow color. It would be described as a small beaned liberian. The quantities produced at that time had not been large enough to create a special market for it and the product was frequently sold together with hybrid coffee. Small quantities sometimes obtained a premium over Robusta on the local market. However, C. excelsa is again attracting attention in recent years.

An other summary of the pros and cons of C. excelsa grown in Indonesia, was given by Hille Ris Lambers at a planters' meeting in 1934 (Notulen 1934, p. 1021). He stated that it grew under soil conditions that were unfavorable for C. robusta and it was more drought resistant by virtue of its thicker leaves and its vigorous deep root system. For instance, C. excelsa grew well on heavy clay soils. It was as susceptible to nematodes as Robusta, but it suffered less from their attacks. Crop failures were, since flowerings were frequent, a fact that meant a division of risks. Flowerings were protected further against rain damage by the large leaves and the fact that the old primary branches and the stem bear flowers. The beans were about the size of Robusta beans, and thus pulping could be done for both with the same machinery. For seedlings the following selection numbers from Bangelan were recommended: Excelsas Bgn.1, 121, 121.09, 121.10, 121.11, and 121.12. In the first two, beans were of medium size, and the others had smaller beans. For grafting, number 121.10 was recommended. This clone gave an average of 10 q./ha. for 6 years, including the first cropping years, and also 1930, a year of robusta crop failure.

Some other kinds of coffee closely allied to C. excelsa have been described as separate species. All have the same luxuriant growth, large leaves, and small berries of C. excelsa. As such we may cite, a form received from the Belgian Congo under the name of Coffea sp. Lamboray. In it the berries were round, juicy, and bright red, and the foliage very dense and highly resistant to leaf disease. The Cultuurtuin obtained this kind from Gillet, the well known plant collector and tester of new plants in Kisantu, Belgian Congo (Cramer 1918-19, p. 27).

A separate and promising species was C. dybowskii, which might best be described (Cramer 1916a, p. 215) as a C. excelsa with lighter green, more supple leaves and oblong, somewhat pear shaped berries. Fruits were larger than C. excelsa, of a brighter, coral red color and slightly striated. C. dybowskii was described botanically by de Wildeman (1901, p. 14). Chevalier mentioned this kind as closely allied to C. excelsa and he found it back along the Kemo River. Thus far little attention has been given to C. dybowskii. A field of it laid out in 1913 at Bangelan grew vigorously and it gave good yields. In some trees the berries were larger than in the original trees and gave beans of an attractive oblong shape.

The resistance of C. dybowskii to berry borer has already been noted, and it is also fairly resistant to Hemileia (Cramer 1918-19, p. 27). It is similar to C. klainii as to its berries; but the foliage is lighter green and very dense, like that of Lamboray. C. klainii was discovered by a missionary, Father Klain, near Libreville (E. de Wildeman, 1904, p. 116). Chevalier, who saw this kind in the experimental plot of Gillet in Kisantu, Belgian Congo, remarked that the fruits were "as large as plums" (Chevalier, Nouveaux documents, 1926, p. 671). This characteristic is not mentioned in de Wildemans' (1904, p. 116) description; he comments only that the fruit had a kind of protuberance formed by the base of the calyx. He reported its fruit was about 2.3 cm. long and 1.4 (de Wildeman, 1901, p. 14).

Chevalier (1919) described a form received as C. excelsa du Mayombe which he said was certainly not Excelsa, but a variety of C. liberica to which he gave the name of C. liberica var. gossweileri. The fruit of this was oblong, somewhat costate, he said "avec des lignes méridiennes sailantes", and 2 centimeters long. Its fruit resembled that of C. klainii, but its leaves differed for they were only 9-13 cm. long (Chevalier 1939, p. 398). C. ocymentis, another new kind from Gabon that was cultivated in the area was described by Chevalier (ibid. p. 403) as having narrow leaves 9 to 18 cm. long, by 3.5 to 6.5 cm. broad, and five lobed flowers. It appeared close to C. abeokuta Cramer and C. klainii Pierre. C. macrochlamys was described by Froehner (1898, p. 268), and was apparently also a species resembling C. excelsa. Its habitat was reported as the Cameroun,

500 to 800 m. above sea level.

Of all the liberioïd species enumerated above, except the last ones, recently discovered, selected clones were included in the collections of the Cultuurtuin. They were mostly clones developed from the best trees among the introduced material or among those grown introduced seed. Since the list of them by van Hall & van Helten was published (1917), they have attracted very little attention.

CHAPTER 18
COFFEA ROBUSTA - GENERAL

CHARACTERISTICS

"Robusta" coffee was introduced into Java in 1900. The first introduction has been fully described in a previous chapter. In 1901 many estates in Java imported additional plants of the new species. All this material was obtained from the Brussels nursery firm of L'Horticole Coloniale, which put the new kind on the market under the well chosen name of Coffea robusta Linden. The name of the director of the firm is thus properly connected with the species which saved the coffee planting industry of Java from ruin.

In some respects C. robusta is intermediate between C. arabica and C. liberica. The growth is vigorous, and the branches are thicker than those of the arabian, and more flexible and denser than those of the liberian. If left untopped it grows into a small tree 6 or more m. in height. The leaves are of a brighter green than those of arabian or liberian and more "wavy" with an uneven surface between the nerves. The edge is undulating. Leaf size varies from 15 to 25 cm. in length, and 10 to 15 cm. in width, with the greatest width at about the middle. The flowers grow in thick clusters on the nodes and are white and fragrant. A large number of fruits per node may set, and 70 to 80 or more berries per node have been counted. In the original description of wild Robusta in Linden's catalog, the dense whorls of fruit are mentioned. "The lower half of the branches bears the agglomerated fruit almost encircling the wood" (Linden 1900, see Cheney 1925, p. 90).

The berries are small, almost sessile, and on a shorter stalk than berries of C. arabica and C. liberica. They are round and when ripe show an even dark red or carmine red color. The skin is thin, the pulp juicy, and pulping easy. The freshly pulped beans have, if placed on the flat, grooved side, somewhat bent sides, while in Arabica they are straight. The beans are small. When dried at a high temperature they are yellow-green in color. The silverskin is difficult to separate from the bean, but if the drying is done at a high temperature, as it is with liberian, there is no difficulty. The proportion of berries to market product is about 4.5:1. Cured Robusta has more aroma than liberian, but it is not equal to that of arabian. The taste of C. robusta lingers longer in the mouth, and it is "chocolate-like".

Although Robusta did not command such high market prices as arabian from Indonesia, it found a ready market in the country itself, in Holland, in other European countries, and in the United States. The favorable market which it found as soon as it was offered in large quantities, the high yields of the originally introduced trees and their first generation of offspring, the healthy and vigorous growth, and the early flowering and fruiting soon made the new kind very popular among planters. Robusta was the favorite Dutch East Indian crop in 1916 according to Baron Salak in the Tropical Agriculturist (1916, p. 77). It is still the most popular kind of coffee in Indonesia. It is also produced on a large scale in the Belgian Congo and seems quite suitable for other parts of west Africa. In the Gold Coast Colony the Department of Agriculture has made careful comparative trials among species of Coffea of robusta, liberica, arabica, and stenophylla and found robusta the sturdiest of the more delicate, highly flavored species (Maxwell 1928, p. 95).

A note of historical interest may be added. Maitland (1926, p. 4) cites from Speke's "Diary of the Discovery of the Source of the Nile", written in 1863, that on approaching Masaka he was met by natives who brought coffee with them. There is no doubt but that this coffee was C. robusta from native gardens.

Coffea robusta is not a botanical name. The species is probably identical with C. laurentii and C. canephora var. sanjuruensis, both indigenous in the Belgian Congo. These forms occur wild in the rain forests of the large Congo Basin from Stanleyville to Coquilhatville. According to Chevalier (1937, p. 67) the early Robusta plants put on the market by L'Horticole Coloniale were raised from seed received from a small planting in the Belgian Congo.

The climatic conditions of the Congo basin are somewhat similar to those of the Robusta belt in Java. Bangelan may be considered as a good place for this. The factory where the main rain gauge is situated is at 350 m. altitude, but this is the lower limit of the fields, which extend to a height of a couple of hundred meters more. The annual rainfall averages 2,661 mm., while it is less in the Congo Basin. Mobaye at 400 m. has an average of 1,641 mm.; Nouvelle Anvers, at 375m., 1,705 mm.; Luluabourg, at 620 m., 1,544 mm. The average temperature of the Congo stations is a couple of degrees centigrade higher than the average of the Robusta region of Java (Braak, 1921, p. 492). By a careful study of figures on rainfall and average crops, Rudin (1935, p. 738) came to the conclusion that the Java estates which gave a yield above average, more than 10 q./ha. for a longer period of years, are situated in regions with a pronounced dry season, a yearly average rainfall of 2,200-2,600 mm., and an average of 135-140 rainy days per year within narrow limits. The optimum altitude lies between 450 and 800 m.

An altitude of 400-600 m. seems especially suitable for Robusta in Java. The better yields come from this zone, and it is better not to go above 800 m. In southern Sumatra the favorable conditions are entirely different. The altitude is often more than 900 m., and the annual rainfall and number of rainy days per year are considerably higher. On an estate where these conditions prevailed, the average yield for 20 years was 11.5 q./ha. A heavy yield from young 3 to 4-year-old plantings followed by lower crops from older trees is characteristic for the moist climate of southern Sumatra. Snoep (1935, p. 982) made an extensive study of the influence of rainfall on the yield of Robusta in Java. A good deal of statistical data on rainfall and yield were compared. The estates belonging to the dry climate group showed greater variations when the annual crops were compared, than those in a wet climate. Generally speaking, the estates at higher altitudes and with a wet climate gave rather low yields.

THE INTRODUCED TREES

Soon after the introduction of Robusta the reports on the new kind were optimistic. One of the first came out in 1905 (van Lennep, 1905) and was quite favorable. It gave a general impression of the condition of the introduced trees, then 4 years old, on 20 estates mostly in the Kediri province in east Java. Some notes about their seedlings, then 18 months old, were also included. Other reports from estate managers about the same time gave details about the introduced plants. When received in Java they were often nearly leafless. Complaints about twisted roots and the small size of the clumps of earth in which they were shipped were general. On the Kepong Estate they were kept in the nursery nearly a year and then, when 50 to 50 cm. high, were set out. Fifty plants were set out at 300 m. above sea level and 27 at 400 m. All the one year old trees at the lower station flowered. The fruit was smaller and took more time to ripen than that of Arabica, which required there about 7 months. The new trees seemed to be very susceptible to green scale, and some showed leaf disease (Lagerwerff, 1903-1904).

Another planter (Versluijs, 1903-1904) observed that his 91 plants put out in January 1901, of which 78 grew very well, showed different types. Some had narrow leaves, others had flat, broad leaves. They started flowering in July 1902. A later shipment was received in October 1901 on the Pondok Gedeh plantations in west Java and put out at once. Eighty-seven trees developed very well and flowered after 18 months in May 1903. One was attacked by Hemileia vastatrix in June 1903 (van Hooff, 1903-1904). The plants of the first shipment were planted at Soember Agoeng at 2,800 feet elevation at Wringin Anom was at 3,500 feet, and at Kali Bakar, 1,650 feet. Some were put out in nematode infested soil. The new species showed itself very sensitive to soil fertility. Where the Arabica had died, the Robusta turned yellow and remained at a standstill. Elsewhere the growth was very rapid, and the trees, then 3 years old, bore well, sometimes more than 50 berries per node. The berries ripened well (de Stoppelaar, 1903-1904).

At Djati Roengoo, plants were received in January 1901. A total of 104 were planted, and 97 grew well. In January 1902 they were one meter high and started to flower. They suffered from green scale but not from Hemileia. Part of the first seed harvested was used for further multiplication, and part was cured as market coffee which was found to resemble C. arabica in taste but had less aroma. This planting of Robusta was described by (MacGillavry, 1903-1904), who remarked that the fruit skin and parchment skin were thin and that he preferred Robusta to liberian because it was not affected by leaf disease, was a quick grower, gave more fruit, and produced more aromatic coffee. As we may see, the first impression of all planters was favorable. Therefore it is not surprising that the popularity of Robusta grew rapidly. It increased further when several experts recommended it to the planters at the ninth coffee conference in Soerabaja in 1907. In the period 1907-1912 most of the estates with arabian in the middle belt cut out the old species and replaced it with Robusta. The popularity of the new species is seen in the rapidly decreasing crops of C. arabica and the still more rapidly increasing Robusta crop. About 1915 this coffee crop passed the highest figure ever reached by C. arabica.

COMBINED PLANTING WITH HEVEA

Another circumstance contributed to the rapid extension of Robusta. The beginning was in 1906, when D. Birnie, the well known planter of Besuki, set out Hevea rubber at Bajoe Kodiel mixed with Robusta coffee. Soon this system found adherents everywhere in east Java, and it may be stated that in this part of the island today no Hevea is put out without interplanting it with Robusta. The original planting is still in existence and is a good proof of the perspicacity of David Birnie, who holds the priority on the system (Schweizer 1931, p. 119).

In the same period, from 1907 to 1912, part of the old plantings of C. arabica were converted into Hevea, and it was soon found that on these old coffee estates Robusta was a very suitable catch crop for interplanting with the rubber trees. It had been recommended before to rubber planters as

such (Cramer 1909d, p. 540 and 1916/17). Its early production, its need for a light shade, and its low growth when topped, made it an excellent companion for young rubber (Cramer 1909d, p. 540). Its crops in the fourth to sixth year after planting compensated for the handicap to Hevea in the middle belt, where at 400-600 m. rubber cannot be tapped until 2 or 3 years later than in the lower plains. That the combination of this coffee and Hevea was popular in east Java from the very beginning, appears from the fact that in 1911, in Besuki province, 831 bahoes were planted with rubber alone and 26,880 bahoes with rubber combined with another crop (Broersma, n. d., p. 80). In east Java and southern Sumatra the planting of Hevea with Robusta as a catch crop became a generally accepted policy. For the latter province it was estimated from actual data that in the third year a crop of 7 q./ha. of coffee was harvested, in the fourth year 13 q./ha., and in the fifth 11 q./ha. (Cramer, 1918, p. 27).

When the two crops are combined with the idea of cutting out the Robusta after 6 or 7 years, the planting can be rather dense so as to get a large early crop. An experiment on growth of Hevea interplanted with Robusta, was compared with the growth of Hevea without such interplanting. It showed that the growth of the trees with coffee was only very slightly behind that of non-interplanted trees (Ultee, 1917, p. 200). In an experiment at the Yangambi station in Belgian Congo, plots with coffee only, 1,059 trees per hectare, were compared with others with coffee, 970 trees, and with Hevea 288 trees, and with plots of Hevea only having 300 trees. The pure coffee yielded 2,394 kg., the coffee planted with rubber gave 2,173 kg., so that the interplanting of Hevea did not seem to have reduced the crop much (I.N.E.A.C., 1939, p. 100).

The advantages of a policy of combining rubber and coffee were explained by Cramer (1916/17, and Publ. Ned. Ind. Landb. Synd. 1917) in a general note on the planting of several crops on the same estate. He cited various data on the actual situation in Indonesia to support his views and mentioned that Hevea rubber and Robusta coffee were often combined. The whole question of diversity of crops was extensively debated in a planters' meeting after a controversy between Cramer and van Hasselt on the subject. The meeting unanimously adopted a resolution expressing the advantages of having more than one crop, or having mixed crops, in the light of the risks of an agricultural enterprise (Loc. cit., 1917, p. 514).

Besides the system of using Robusta as a preliminary and temporary planting, or catchcrop, there is the system of permanent combination. This system became especially popular in the easternmost part of Java, in Besuki; and the Research Institute in Djember encouraged planters to adopt it. Schweizer (1931, p. 121) published several articles in which he recommended it, giving particulars about the results. He described a planting of Hevea, 8 by 8 meters, with 3 row of Robusta between the rows of rubber; and after 20 years the Robusta was still yielding a crop and expected to continue. Profits from such combined plantings are higher than when the same areas of coffee and Hevea are planted separately. When high grade Hevea clones are available, the situation becomes more favorable. The pruning of the rubber trees can be better planned, and the Hevea clones lending themselves to combination with coffee can be selected.

These superior Hevea clones are selected for a light, narrow crown, a high stem, and a long wintering, so that the coffee gets a maximum of light. Also the kind of coffee may be chosen especially for this system. In this connection Congensis Hybrids were mentioned. Schweizer cited Birnie's recommendation for the permanent combination of a wide planting, 18 or better still, 23 meters, between dense rows, with 4.5 meters distance in the row for the Hevea clones. The coffee was planted in between with *Loucaena* as a shade tree. When a permanent combination was intended, the question of the planting distance for the Hevea trees was an essential problem. The Hevea could be put out in fairly dense rows, or double rows separated by broad belts of coffee. This system of planting rubber rows, with belts of Robusta between them, was first described in detail by Schweizer (1935, p. 1039). The advantages such as protection against windstorms and very dry winds were summarized in his conclusions. A little later Schweizer (1939b, p. 81-82, discussion p. 87) published additional information on the subject.

When single rows of Hevea were planted with the intention of retaining the coffee permanently, the rubber trees were planted one meter apart in the row, preferably oriented north to south, and the rows placed at a distance of 25 m. with several rows of coffee between them. The avenue system was different in that under it the dense rows of Hevea trees eventually became a closed planting. Here the rows were about 8 m. apart, with 1 or 2 m. between the trees in the row. On an old coffee estate still having a factory for this crop and still more or less oriented to coffee production, the belts between the rows could be planted with coffee. However, it was to be realized that coffee was only a preliminary crop, a catchcrop, which was to be taken out when the rubber began to produce too much shade (Kuneman, 1939, p. 460). The system of row plantings or "paggerverband" became very popular for several years in the easternmost part of Java in Besuki, where, as already stated, it was advocated by the research station and widely applied. The system was first used by one of the

most powerful planting concerns there, and gradually it was adopted by virtually all planters. A study of fields where Hevea had been combined with coffee, and where subsequently the Hevea was partially cut out so as to bring the trees into an avenue planting, led to the conclusion that the system had a favorable influence on the rubber production per tree. The coffee production was also higher than the production per unit of land occupied by a pure coffee planting (Snoep, 1932, p. 889). Good photographs of coffee belts between rows of rubber, "pagers", were published by Schweizer in 1940b, (p. 1668-9).

VARIABILITY OF ROBUSTA

Generally speaking, Robusta is no exception to the rule that all species of coffee studied so far show great individual variations if trees are compared while the parts of the same tree are fairly uniform. In this respect it holds an intermediate position between C. arabica and C. liberica. The characteristics of the fruit size, its color, and the shape of the discus, for instance, among trees of the same seedlings population, do not vary as much as do those of C. liberica. However, since the size of the bean, so important from a practical point of view, has been studied more closely, especially by Schweizer and Hille Ris Lambers, and striking differences have been found to exist. Through single tree selection, vegetative multiplication of large-seeded clones, and hybridization, remarkable progress in increasing the size of the bean has been achieved. In the country of origin, forms differing in this respect seem to be under cultivation. A large beaned C. robusta, the "Improved Casengo" in Angola, has been mentioned by Janssens (1930, 117p). The trees of a population like Robusta may show great differences in individual production, in the same way as already described for C. arabica.

Unlike the latter, Robusta has not developed a number of well fixed hereditary varieties, but sometimes it shows a tendency to form them, parallel with the C. arabica varieties. Among the seedlings of the first generation of Robusta in Java, some red-leaved and "bullata" trees, "little cabbages", as the planters called them, were found. When it is considered how closely the first trees introduced were watched it may be considered certain that if other variations had occurred among them, they would not have escaped attention. Cramer (1908b, p. 531) attributed these "sports" to mutation, although the second generation did not repeat them, but in still further generations they might appear again. The bullata characteristic once appeared in a crossing of Robusta BP.42 and was found to be associated with abnormalities of the chromosomes. Such varieties are without practical value, since the trees are generally less productive.

However, they are very interesting because they show that except in chromosome number, Robusta ($2n = 22$) stands genetically nearer to arabian ($2n = 44$) than to liberian ($2n = 22$) where a red-leaved or a "bullata" tree has never been observed (Cramer 1908b, p. 535). Since this indication of relationship with coffee was recorded, Vavilov formulated his "Law of homologous series in variation" and proved by numerous cases that closely allied Linnean species were characterized by similar and parallel series of varieties (Vavilov 1922, p. 58). The parallelism between C. robusta and C. arabica, in contrast with C. liberica, is similar to the one described by Vavilov for Triticum compactum and T. spelta, which are genetically closely allied to T. vulgare and repeat exactly all its varieties (Vavilov, loc. cit., p. 54). It is curious that in the coffee species closely allied to C. robusta as C. guillou, C. canephora, and C. ugandae coffee such variations have never been found as far as is known with the one exception of the yellow fruited C. canephora already mentioned. However, this may be attributed to the very small number of trees of these other robustoid kinds which have been introduced, compared to the hundreds of Robusta plants imported into Java. In a description of various clones, some other forms with divergent characteristics were mentioned by Hille Ris Lambers (1938, p. 186). Robusta clones were known, for instance Robusta SA.168, in which the berries were yellow, not red, when fully ripe, comparable to the "amarilla" variety of C. arabica and the yellow fruited C. canephora just cited. Some Robusta clones such as Robusta Bgn.209.05 had the "purpurascens" characteristic. Others exhibited polyspermy or false polembryony. One clone, SA.207, formed primary branches which, if there was sufficient space, grew downwards vertically. It might be called a "pendula" form.

As a last divergent form the so-called "lanang", the native word means "male", type of Robusta must be mentioned. It sometimes originated among seedlings of certain clones. The whole appearance of the tree was quite different from that of the parent clone. It resembled the Mokka variety of Arabica closely with its short internodes and smaller, narrow leaves densely placed along the branches, often with a strongly undulating edge and with ribs forming a small angle with the midrib. The base of the leaf was wedge-shaped, and the variety could therefore be called cuneata. The fruits were also smaller than those of the mother clone. From a practical viewpoint this variety was of little interest, but Schweizer used it for making crosses in order to obtain a tree with a more open habit, better suited for moist climates. The clone Robusta BP.25 gave a certain percentage of "lanang"

plants among its seedlings. When one of these seedlings was multiplied by seed, the progeny contained about 10 per cent of lanang plants (oral information from Schweizer). In the Economic Garden in Buitensorg, to seedlings from Robusta Bgn.59.01.01 showed the same variation, one to a slightly higher degree than the other. Compared to the mother clone grown next to them, with leaves 12 to 24 cm. long and nearly half as wide, the "lanang" had leaves 6 to 12 cm. long and $1\frac{1}{2}$ to 6 cm. wide. Perhaps something is wrong with the chromosomes. The variation has not been recorded for other species of coffee, but similar types have been observed among hybrid seedlings.

The variations mentioned in Robusta are purely of scientific interest. The trees showing the abnormal character are poorer yielders. The same is true for trees showing a tendency toward flower virescence or "little stars". It has even been found hereditary in Arabian and in liberian forms. The degree to which it is developed may vary. In extreme cases small green leaves are formed instead of petals. They wilt like the petals of a flower after some time and then form clusters of dry brown leaves resembling exactly the clusters of dried up petals found on the trees when a drought has set in after a flowering. This is an instance of the "Verlaubung" described by Pensig (1921, vol. 1, p. XII). As we have already stated, such abnormalities are stable when the tree is multiplied by grafting. The experimental garden of the Besuki Institute at Djember contains some of these virescent forms of robustoid and liberiod species. Schweizer described a Robusta tree in which not only the petals but also the anthers and the stigmas became small leaf-like organs (1932a, p. 57). This was an instance of a complete transformation of all the whorls of a flower into real leaves and has been called "cloranth" (Delacroix 1911, p. 15).

YIELD FIGURES OF COMMERCIAL PLANTINGS

From the beginning, the yields of Robusta in Indonesia were much higher than those of the two older species, although the estimates based on the very first plantings of only 50 to 100 trees were too optimistic. While the yield of Robusta is generally not as capricious as that of *C. arabica*, a table showing average yields at increasing ages might create a mistaken idea of the production, which varied greatly in successive years, even on an estate in a favorable situation. In 1912 Wurth estimated 9 q. as a fair yield for Robusta for the third year, 13 to 18 q. for later years. This estimate was made for estates on the Smeroe, where conditions were generally good (cited by van Hall, 1912, p. 641). In 1918 Cramer stated (q. v. p. 419) that the average yield of Robusta plantings could be estimated at 10 to 15 piculs per bahoe or 9 to 13.5 q./ha., and under favorable conditions at 20 piculs or 17.5 q./ha. He had seen this last yield maintained for several consecutive years. Sladden (1933, p. 33) mentioned 800 to 1,100 kg./ha. as an average yield for *C. robusta* at Bangelan and gave similar figures for *C. ugandae*, *C. quillou*, and *C. canephora*. Ultee (1924, p. 1539) estimated an average of 9 q./ha., taking failures and berry borer damage into account, as above the average for Malang estates in 1924. He cited an estate on the Keloe mountain which gave an annual average yield of 14 q./ha. in 1918-1924 including one bad year caused by a volcanic eruption. *C. quillou* has been called by planters "the experiment field coffee" because in some experiment stations in small areas crop of 44 q./ha. have been obtained, but this has never been equalled in commercial plantings (Ultee, 1924, p. 1540).

Robusta was first planted in 1907 on the west coast of Sumatra on Liki Estate, but extensive plantings were not made until 1927-1932. Although the financial results were disappointing for various reasons, the average yield was fair; for ordinary estates it was estimated at 9 q./ha., for estates under optimum conditions at 12 q./ha. (Kouchenius, 1936, p. 13). The average yield for the estates in southern Sumatra in 1935 was 5.34 q./ha. for the Lampong districts, 9.18 q./ha., for Palembang, and 7.39 q./ha. for Bencoolen (van Heusden, 1936, p. 694). Average yield figures for estates in southern Sumatra were also published by Hoedt (1930, p. 207, Table 15), but, they were only rough figures, not suitable for comparisons. For some estates the annual averages fluctuated around 10 q./ha., but in most cases they remained considerably lower.

For one of the best Robusta estates in Java that was on the Keloe mountain on volcanic soil, Ultee (1929, p. 1737 & 1740) cited an average over many years that came out to 20 piculs per bahoe. In one decade there were, as extremes, crops of nearly 30 piculs and others of just over 10. On an estate where the land had been planted and replanted with coffee since 1876, the yield level was about 10 q./ha. From a new planting on virgin forest land dating from 1934 a yield of 27 q./ha was obtained. Such figures did not occur in replantings (Sneep, 1941, p. 645). For Besuki, where a good deal of the Robusta was planted on virgin soil, the yield of the coffee fields not mixed with Hevea was 7.2 q./ha. for the period 1920-1930, but leaving out the bad years of 1924, 1926, and 1930 (Scheltema 1932, p. 208). As we have already noted, an average of 10 q./ha. over a period of many years was considered as very good for Java. In 1915 a yield of 7-9 q./ha. was cited as satisfactory, and 13 q./ha. was considered a very large crop (Anon., 1915, p. 203).

For a 12 year period, 1923 to 1934 inclusive, the following average yields were recorded. For

the Keloed mountain, 7.8 q./ha.; for the Kawi estates, 5.7 q./ha.; for the southern mountains, 8 q./ha.; for the dryer estates on the Semeroe, 8 q./ha.; and for the wetter ones 5.1 q./ha. (Snoep 1936c, p. 1002). Besides these general data, more detailed information on annual crops of a number of estates was published in the form of graphs for the years from 1924 on by Snoep (1939a, p. 804 and 805).

For the Malang Research Institute's station at Soember Asin, largely planted with improved material, the average for the last decade came to 10 q./ha. (Hille Ris Lambers, 1941, Discussie, p. 1531). Interesting figures for a plantation over 30 years old were cited by the same author (loc. cit., p. 1522). The average annual yield of this planting during the period 1907-1921 was 5.60 q./ha.; in 1920-1924, 4 q./ha.; in 1925-1929, 18.5 q./ha. It seems that 1930 was a bad year, with only 1 q./ha. after the extreme drought of 1929, and this brought the average annual yield for the period 1930-1934 down to 11.8 q./ha., while for 1931-1935 it was 14.7 q./ha. For 1936-1940 the average was 8.7 q./ha., and for the entire period from 1907 to 1940 the average was 9.3 q./ha.

An attempt can be made to calculate the yield of Robusta per hectare in Java from published statistical data (Anonymous, 1941, p. 141). In 1939 there was a total estate area in Java of mature Robusta of 73,636 ha. including 15,386 ha. in which Robusta was combined with other crops, in which was included rubber and Robusta on 14,771 ha. The total yield was 48,146 tons, which indicates an average yield of 654 kg./ha. It must be taken into consideration that 1939 was a year with a good crop.

From all these data together the average yield of Robusta and closely allied species can be estimated over a long series of years at about 6 or 7 q./ha. Under favorable conditions this average may reach 10 q./ha. or more.

CHAPTER 19
THE ROBUSTOID KINDS

GENERAL

In the robustoid group there are several other species of coffee which show great resemblance to Robusta. Some are even so similar that they can better be included with Robusta itself. The systematic position of many of the species often described on the basis of incomplete material is very uncertain. Had not species such as Coffea laurentii and C. canephora var. ganjuruensis been adorned by their own scientific names, they would be distinguished as botanical species. They are no more different from typical Robusta, than the various types which compose the mixture to which this name has been given differ among themselves. There are, however, a few different types which can be maintained as separate "small" species and which will be enumerated here. The main characteristics and the history of their introduction were described by van Hall (1912). Hille Ris Lambers (1928, p. 1529) took C. laurentii as the prototype, since it is considered identical with Robusta in the stricter sense, and provided a good review of the various allied species. Some of these small species themselves contain various forms. For C. canephora a number of different, well defined varieties have been described. A list of ten names may be found in the enumeration by de Wildeman (1910, p. 368). It contains one form, probably identical with C. robusta Linden sensu strictiori (= C. laurentii), viz., C. canephora var. ganjuruensis.

As such, these small species have little importance for practical planting. Often considered very promising when first introduced and used to a certain extent for commercial plantings, they did not come up to anticipations, and they are hardly used at present. On the other hand, they have spontaneously hybridized with the ordinary Robusta, and, among these hybrids, some have acquired a place in the practical planting industry.

QUILLOU COFFEE

This variety was introduced at Bangelan in 1901 from Libreville, French Congo and was mentioned by Kramers in September 1901 (1901-1902, p. 562) as having been put out in the nursery at Bangelan. The name probably refers to a river in west Africa, since there are several rivers with the name Kwilu and Louilou (Wurth 1912a, p. 383). Only one introduction took place. Originally 33 plants were put out, but apparently a few of the introduced plants were used for grafting. According to tables for yields of the introduced trees, there were 30 trees in production (Jaarboek 1901, p. 119; 1905, p. 128-129; 1907, p. 187). The trees planted at the end of 1901 produced ripe fruit as early as the third year, 1904, and in 1905 they produced at the rate of 24.32 piculs per bahoe (Jaarboek 1905, p. 127), or 21 q./ha.

From the introduced trees the numbers 19 and 22 were selected in Indonesia as mother trees, and from the first generation composed of mixed seedlings of the introduced trees, the numbers 79, 88, and 140 were chosen. The trees from them were fairly uniform, much more so than Robusta. In the beginning it was thought that it was a kind of Robusta, but as the plants grew older, several differences became apparent. The leaves were narrower, of a brighter green than those of Robusta, with marked nerves and bubbled between. Young leaves at the end of the branches were often brownish, while in Robusta they were greenish or yellowish. Branches were more horizontal, denser and ramified, giving the tree a broad shape. Stems of old untopped trees of C. quillou remained straight and erect and did not hang over as easily as did those of C. robusta. Growth was vigorous, and the tree only very slightly susceptible to Hemileia. The berry was angular and oblong, and not so rounded off as that of C. robusta. When ripe, it was a bright red and the skin and glucose layer thin. The proportion of berries to market coffee ranged from 3.5:1 to 4.5:1, more favorable than in the case of Robusta. The pulped coffee was brownish, and the parchment skin brown and thin. The silverskin brown and not green as in Robusta. It could be called more correctly copper skin (Cramer 1918, p. 420).

At Bangelan the plantings of C. quillou were highly productive. Two plantings of Quillou Bgn. 121 at Bangelan of a very uniform appearance gave, as an average, over 15 and 18 years, nearly 1,800 kg. per hectare. In a plot experiment repeated 6 times it gave nearly 14 q./ha. in the first crop year (Ferwerda 1935, p. 10). In the years 1905 to 1910, when Robusta had become popular, the variety known as Quillou was also frequently tried on estates, but it was disillusioning, especially on sandy soils.

In 1912 an inquiry was held among the planters of the Kelced mountain, where there were many coffee estates, all on very sandy volcanic ash soils. The answers may be summarized as follows: in the nurseries the Quillou grew normally, just as Robusta, and the young plants in the field were also as good as those of Robusta. Up to the second year the growth was slightly slower, and sometimes rust did some damage, but after the second year the Quillou caught up with Robusta again. However, productivity of C. quillou on sandy soil was much less, but it generally surpassed C. robusta

in uniformity (Wurth 1912a, p. 344). Here, and under other conditions, C. quillou was disappointing. It lost in favor of the planters and was virtually abandoned.

In older publications, C. quillou from Bangelan has been frequently contrasted with a kind known as C. canephora var. kouilouensis or kwiluensis, said to have been obtained from the Parisian nursery firm of Vilmorin. A description of this type in Madagascar and a photograph of it (Ledreux, 1932, p. 124) showed certain resemblances to the coffee of Bangelan, for instance, a reddish silver-skin. The names "Kwilensis", "Kouilouensis", and "Quillou" seem to have been confused. A further change is apparently the name "Conillon" coffee belonging to C. canephora (see the book Jotapen 1915, p. 23), which one would suspect to have originated with the word "couillou", in which the u's have been replaced by n's. The kind called "Hibrido de Siberia" in that book (loc. cit., p. 24) is evidently an alteration of Liberia in the same style, hardly an introduction from Siberia.

Some material has been introduced into the Cultuurtuin under the name C. kouilouensis which seems different from the name C. canephora var. kiwiluensis given to a variety introduced from the Serres in Leken into the Cultuurtuin in 1907 (Jaarboek 1907, p. 184). What became of these latter plants is not known. The information in the list of van Hall & van Helten (1917, p. 23) on "Kouilouensis", which is said to have been introduced from the Serres in Laeken as seed, is probably incorrect and based on a confusion of the two similar names. For many years two clones called C. canephora var. kouilouensis were grown in the Cultuurtuin, but were probably hybrids with C. congensis. Van Helten's own data on it (1918, p. 43 and p. 50) are contradictory. The C. canephora var. kouilouensis is said to ripen as a crop more regularly and earlier than Robusta. An excellent stand of C. canephora from Kwilu, in full bearing in the Botanical Garden at Victoria, Cameroon, was mentioned as early as November, 1901. However, its continuous flowering and ripening of fruit was considered an objection to large-scale planting (Gentil 1902, p. 248).

Portères (1939, p. 18) states that on the Ivory Coast a robustoid species, C. canephora var. kouilou, from Gabon, also called "petit Indénié", was planted on a large scale. This kind, coming from the same country from which Bangelan got its "Quillou", may be identical with the latter. According to de Wildeman, the variety called C. canephora var. kouilouensis is indigenous and also is cultivated in the Belgian Mayombe (de Wildeman, 1905-1907, p. 331). Chevalier states that a specimen from Angola, identified by Welwitsch as "Liberica", was in reality this C. canephora var. kouilouensis Pierre. This variety is widely cultivated in Gabon, in the lower Congo, and in Angola, as C. wildemanni Pierre. To this variety belongs also C. canephora var. hiernii Pierre ex de Wildeman (Chevalier 1939, p. 397). All these somewhat confused references make it probable that C. canephora var. kouilou or kouilouensis is the same as the kind introduced at Bangelan as "Quillou coffee" and subsequently grown in Indonesia under that name.

COFFEA CANEPHORA

This variety was introduced several times from various sources. A strain of it, fairly widespread in east Java, came from Djati Roenggo Estate in central Java, which obtained its original plants from L'Horticulture Coloniale, Brussels (van Hall 1912, p. 756). Coffea canephora is indigenous in west Africa in the rain forest as well as in the deciduous forest, in gallery forests, and in forest islands in the savannah (Portères apud van der Meulen 1939, p. 72). It is found in Gabon, where it is known as the coffee of the Ishiras (Froehner 1898, p. 269).

The typical C. canephora is characterized by the brownish or bronze tint of the unripe berry. At the base of the corolla tube a slight coloring of red can be seen, also extending over the discus, which often protrudes as a pink pinhead just after flowering. The berries are a bright red, generally finely striped with very narrow, yellow lines, but the form is generally narrower, more oblong than the Robusta berry. The leaves are generally narrower than those of Robusta and are often somewhat leathery. The young leaves are bronze, and the dense branches are thinner than those of Robusta. It is often a good yielder, but generally it has been found much more susceptible to leaf disease.

There is a narrow leaved form of typical C. canephora, equally susceptible. This kind has bronze colored young leaves. The types of C. canephora from Djati Roenggo and Djabocong and the C. canephora from Madagascar from Bangelan belong to this type. It yields well, but it is susceptible to Hemileia, which often appears only after a couple of years when the trees start production. The attack may strip the trees of leaves, but this will never be the case with the other robustoid kinds (Wurth, 1912a, p. 383). Another C. canephora, a broadleaved type, is more like C. robusta.

In a dry year it showed also more resistance to drought (Ultee 1926a, p. 631) than Robusta, but it never became popular, since planters were afraid of its deficient resistance to leaf disease. The Canephora strain Bgn.3 Madagascar had a certain popularity as a stock for grafting.

COFFEA UGANDAE

C. ugandae Cramer is one of the oldest robustoid kinds, and it was introduced into the Cultuur-

tuin in 1903, where Cramer(1908d, p. 733)found it and described it. "Uganda" coffee is probably identical with C. arabica var. stuhmannii Warb., which Stuhlmann collected in large quantities near Bukoba at 1,200 m., and it was described by Froehner (1898, p. 263). A well marked type with an open growing habit, it was marked by fewer secondary and tertiary branches than Robusta. The branches had short internodes bearing leaves only at the end, and bent. The whole tree was narrow, the growth less vigorous than with other types noted thus far. Leaves had undulating edges with small gutters as though bent. The flowerings were not concentrated. Hybridisation took place easily. Some C. ugandae numbers at Bangelan may in reality be hybrids of C. ugandae with other robustoid species, for instance, Uganda Bgn.2.08. The berries were surrounded by the stipulae, often in a nest of small leaves. They were stalked and not so numerous per node as those of Robusta. They were of an even pink color, small, and oblong. The tree appeared strongly resistant to leaf disease but it was very susceptible to berry borer (Hille Ris Lambers 1928, p. 1530). It is a type apparently suitable for humid climates (Ultee, loc. cit., p. 631). In 1911 van Helten (1911, p. 715) again recommended C. ugandae to planters, describing a planting which was laid out in Buitensorg in 1909 and which remained free from Hemileia and Corticium diseases. The species introduced afterwards, under the name Coffea bukobensis, belonged to the same group or was identical with C. ugandae. Somewhat similar to it was a kind introduced by the Malang Institute from Uganda by den Doop under the name "coffee from Uganda, free from berry borer". A planting was made at Soember Asin in 1925/26, and the trees were very uniform. However, when fruiting started they were not all free from the pest (Hille Ris Lambers 1931a, p. 687). The leaves showed a less undulated edge that was less gutter-like than in C. ugandae and fruit clusters were near each other on the branch. From this kind the clone Uganda SA.425 was developed.

OTHER KINDS

In the clone collection of the Cultuurtuin all these species were represented, sometimes by grafts of the originally introduced trees. A few other introductions were also received under the names of "spontan", "Ivory Coast", and "Touba", all from the French west African colonies. The first two resembled each other. The leaves were dark green and narrower than those of Robusta. The berries were small, of a dark, even red, and round. The Touba coffee resembled C. quillou, but with smaller berries, of a darker red. It was probably identical with Coffea macclaudii Chevalier. There was also a clone developed from a direct introduction of wild Robusta from the Belgian Congo, not distinguishable from the ordinary Robusta, and a Robusta clone from an estate in central Java, with narrow, mokka-like leaves and small round berries.

CHAPTER 20
IMPROVEMENT AND DEGENERATION OF ROBUSTA

HAS ROBUSTA DEGENERATED?

Several times planters expressed fear that their Robusta coffee was showing signs of degeneration. They meant by this word "a partial loss of the valuable characteristics of the plant" (Wurth, 1917, p. 341). From the very beginning planters had been warned against a possible increase of diseases in the newcomer, the logical consequence of what had been observed with *C. liberica*, not degeneration of the tree, but increased virulence of *Hemileia* rust. Thus, at the Coffee Planters' Conference in Soerabaja in 1907 Cramer (1907, Conclusion 11, p. 735) drew attention to the possibility that something similar might happen to Robusta. As early as 1912 there were complaints that it was not yielding in the same manner as it did in the first year. Growth and yield were thought to be declining, and leaf disease was thought to be increasing. According to Wurth (1912, p. 19) it was certainly true that leaf disease had definitely increased. In 1916 an inquiry was organized among the Malang planters about the alleged "degeneration of Robusta". In 20 replies this degeneration was denied, but in 7 the opinion was expressed that Robusta had become more susceptible to leaf disease (Meylink 1917, p. 8). About the same time an experienced planter in the Malang district, H. van Kleef, denied the degeneration and attributed the assumption that it took place, to occurrence of adverse external conditions. In 1922 Wurth denied that degeneration was the cause of the poor results of some of these plantings (1922, p. 27) and attributed them to other causes. In 1926 Bally (p. 163) expressed his conviction that in the last two decades Robusta had even improved. A few years later Ultee (1926a, p. 629) discussed a similar problem, the future of the coffee production in Indonesia and mentioned that sometimes "explosions" of leaf disease might occur, but that generally unfavorable external conditions were responsible for them. Hybrids proved themselves more resistant in this respect with *C. canephora* less resistant.

In 1932 and 1933 complaints were again heard about an alleged degeneration of Robusta. The problem was discussed in the Malang Planters' Association, and Ultee (1932, p. 254) concluded that if there had been crop failures, they had to be attributed mainly to bad weather conditions. In his opinion the existing plantings could still give very good yields, although they might decline very slowly by increasing in age. In view of this last danger many estates were then taking preventive measures by re-opening fields or by gradually rejuvenating the trees. Shortly afterwards Ultee (1932a, p. 774-777) confirmed his view that there was no degeneration of Robusta, since there were no indications of slower growth, less satisfactory setting of the fruit after the blossoming, or higher susceptibility to diseases and pests. The leaf disease already observed in some of the plants first introduced did not increase, although this had been feared at times. New diseases and pests did further damage in later years, and it would not have been surprising if the average yields had become lower than 15 years previously. However the opposite was the case on most estates, thanks to a more intensive technique and to the increased role of improved planting material in the production.

In connection with plans for renewed introduction of seed from the country of origin Ultee (1932b, p. 304) remarked that even in the old days an almost unconscious selection had been applied on estates, since the planter generally took the seed he needed from his best trees, free from disease. For this reason the resistance of the planting material had been increased. This renewed introduction of seed from the country of origin was often deceptive, as such seed could give plants suffering more from leaf disease than those grown from local seed.

Shortly afterwards Ultee came back to this point (1933, p. 369). He defined degeneration as "the transition of the original state to a less satisfactory one" and thought it highly improbable that such a transition had taken place. In his opinion (1933, p. 371) the average crops might be somewhat lower than before the increase of various diseases and pests such as dieback of tops, branch borer, and berry borer, but the size of the bean had certainly increased.

So far there had been no evidence that an increase in *Hemileia* attacks had taken place. How easily a temporary change in the situation might frighten the observer was shown by Wurth's (1912, p. 10) pessimistic opinion about the increase of *Hemileia*. Now, many years later, there is no evidence that the leaf disease attacks Robusta more than it did at the time of its introduction in 1912. In discussing the history of *Hemileia* rust on Robusta the opinion of Pfaltzer (1936, p. 988) may be cited. He had the data of the Malang Research Institute at his disposal and stated, after study of the records, that sometimes in the annual reports significant revivals of leaf disease on Robusta were recorded, but that *Hemileia* was never a factor of great importance in production of the crop.

Degeneration may also mean that the hereditary characteristics of the tree have changed, that its constitution has deteriorated. It is in this sense that de Stoppelaar discussed it. In a first lecture (1936a, p. 313 to 317) he developed his views on the degeneration of Robusta which he at-

tributed to wild crossings which had accumulated undesirable characteristics in the present seedlings. Fortunately, the seedlings still contained some excellent types which could be the basis for further selection.

In the discussion (loc. cit., p. 316) Gandrup remarked that seeds had been secured again from originally introduced Robusta trees and plants raised from them. Their appearance was good, and yield was not bad. Attempts were made to find better types among them, less variable than those he was using. However, nothing came of this search, and the same was true of new introductions of Robusta in later years. Gandrup added that some of the best selection numbers showed components from other species. It is questionable whether this is a disadvantage.

Shortly afterwards de Stoppelaar (1936, p. 1160) returned to this topic. Again he explained that in his opinion the Java *C. robusta* contained many elements from closely allied species, from *C. quillou*, *C. canephora*, *C. ugandae*, etc., a fact that is not surprising since, generally speaking, Robusta must be cross pollinated to set fruit. He cited several cases known to him in which very good trees gave seedlings with poor characteristics, great susceptibility to diseases and pests, small or even very small beans, and so on. He even cited a planting grown from seeds of the well known Robusta BP.42, which consisted of more than 90 per cent of trees without any value, with narrow leaves, suffering from infantilism and branch borer, and otherwise defective. All these poor types were replaced by seedlings of Robusta SA.34, which developed so well for two years that the soil could not have been the source of the trouble. However they showed many defects in their third year. A seedling planting from estate mother trees was poor. Nearly all trees were stumped and grafted with graftwood of the same mother trees, and the planting became excellent. Uganda Bgn.3.02, was excellent on his estate as a clone, but the seedlings were poor.

The conclusion was that Robusta degeneration and that certain disquieting manifestations of the accumulation of bad characteristics could be observed in a seedling planting. The reassuring point was that such a planting also contained some very good types, and plantings established with legitimate seed contained even more very good types. Such types could be fixed by grafting and all planters should be advised to preserve their valuable property in this manner. De Stoppelaar contended that by this method the world's fruit production became great, why would coffee be an exception? Whether there was degeneration or not, the industry must be directed toward a perfection of the individual tree. This could be done by systematic crossing, and thousands of perfected types were needed to suit all the different demands of the external conditions and to resist the present and future diseases and pests.

In the discussion most of the participants stressed the external conditions, and the questions centered on whether grafts or seedlings were preferable. The view that the impoverishment of the soil played a role in this whole problem of degeneration was developed by Coolhaas (1941, p. 71) in the discussion after his lecture on improving old fields by grafting in the field. He said that the good results formerly obtained from unimproved material could no longer be thought of as a consequence of the erosion of soils and perhaps of other causes.

In connection with such remarks reference may be made to two other lectures given about the same time. Hille Ris Lambers (1936a, p. 974) said that "even the oldest plantings of introduced trees contain elements which show close resemblance with robustoids introduced afterwards in the Netherlands Indies such as Uganda, Quillou, and Canephora". This made it pretty certain that in the country of origin hybridization must already have taken place, and the same could be said of the robustoid kinds introduced subsequently. The other lecture was by Snoop (1936c, p. 1002), who reported an interesting survey of the average yields of Robusta in the province of the Malang Research Institute, and remarked that sometimes it was argued that the yield of Robusta shows a downward trend. Statistical data did not support this view. It seemed fairly certain that an unfavorable distribution of the rains combined with the branch borer caused a period of low productivity, perhaps as an after-effect of previous excessive yields.

The question of the influence of age on the productivity of a planting frequently arose. At Soember Asin, data over periods of many years on ordinary unimproved plantings, fully comparable with estate plantings, have shown that the yielding capacity of the oldest 24-years-old planting was precisely equal to that of younger plantings 13 and 14 years old. The trend of the annual yield figures in later years was similar.

The old fields of Soember Asin which had been stumped and grafted, reached a yield level of 16 to 18 q./ha. for the "proven" clones, and for the old non-rejuvenated fields this level could be put at 12.5 q./ha. Selective grafting of the poor yielders only, practised on many estates, offered a chance to obtain a proportionally still greater increase of yield. The young replantings of improved material in the province did not mean a complete change, although there were many which were giving fair and even handsome yields. The grafts were in advance of the seedlings. Very roughly speaking, they may be said to have given 20 to 40 per cent more in the first years, and the figures

did not show any indication that this surplus decreased with age. The external conditions were discussed briefly. For estates with a moist climate at a higher altitude there seemed to be little chance that technical treatments of the planting, the soil, the shade, and so on could improve the situation. Here the new products of selection offered the best prospects. In this connection the "Congusta", or "Conuga", hybrids were cited. The conclusion by Snoep was that if a rational treatment was applied to the planting of shade and to the soil, and if the results of selection were used advantageously, most estates of Java need not be concerned about their future production.

This sound reasoning, supported by a good deal of experience and a clear insight into the problems connected with the whole degeneration problem, seems to settle the question with the answer that there are no signs that the Robusta in Java is declining in productivity or that its hereditary characteristics are deteriorating. Since the question will certainly rise again and again, just as it came up in the last half century as regularly as years of high and low yield, there is little hope that the evidence compiled here will give the right answer. The "degenerationists" will bring forward their theory without taking it into account. The alleged degeneration of Arabian and Liberian coffee and the doubting attitude of many planters with respect to Robusta on this point has remained unaffected by all the evidence to the contrary: Vogler's data on the yield of arabian coffee, Cramer's experiments and observations of Liberian coffee, Wurth's criticism, and Ultee's common sense.

IMPROVEMENT AT BANGELAN

A good deal of attention has been paid to the improvement of planting material with Robusta and to the production of improved seed. A concise sketch of the history of introduction and selection work was published by Hille Ris Lambers (1930, p. 191). The first station to start this work was Bangelan. This station has been visited on several occasions by foreign research workers who reported the work being done there. The essential points were well explained by Coleman (1931, p. 1 to 19) in a description of the research work on coffee in Java. A good special description of the Bangelan Station with data on the climate and soil, on the earlier history, and on selection is in a well illustrated article by Sladden (1933, p. 3).

Bangelan is situated in the middle belt and thus well located for selection experiments with Robusta. From 1907 on, seed from individual trees were set out separately, and from 1908 on fields were planted with seedling offspring from trees selected for their high merit. A few were chosen from the 24 Robusta trees introduced from L'Horticulture Coloniale in Brussels, viz., no. 104, 105, and 119; others, the first generation, from a field planted with a mixture of seedlings descending from them viz., no. 59, 72, 78, 83, and 124 (Cramer 1927b, p. 1254). The last number was chosen on account of its great vigor (Jaarboek 1907, p. 197). In the fields mother trees were again selected and numbered accordingly. In a field with seedlings of R.124, for instance, these new mother trees received the numbers R.124.01, 124.02, and so on. Again these new mother trees were used for laying out additional seedling fields. In later years, especially since 1914, when a change was made in the supervision, material from introduced trees and from high yielders on estates and also from other selection stations such as Soember Asin (Jaarboek 1916, p. 42) was introduced and multiplied further by the same method. Thus the station gradually acquired large plantings of successively improved generations.

In 1911-1923 the best of these fields were used for the production of seed for outside sale (Cramer 1916c, p. 405). After earlier unsuccessful attempts, large-scale grafting was introduced in 1915 and used at first to make a museum of small plots of all mother trees of the station (Jaarboek 1916, p. 43). The establishment of the clone museum at Bangelan was described in 1924 (Cramer 1924, p. 85). In 1918 to 1919, when enough graftwood became available monoclonal fields of one hectare of the best mother trees were established (Cramer 1927b, p. 1253). After 1923 seed for outside sale was taken from these monoclonal fields and delivered under the number of the mother tree, permitting the buyer to test the offspring and to order more identical material if results were satisfactory (Cramer 1927a, p. 88). A brief description of the method of the selection at Bangelan may be found in the "Korte Gids" (Anon., 1932), which also reproduced, a photograph of "Robusta 124", the mother tree of R.124.01, in full flowering, and a map of the fields.

The effect of the seedling selection was revealed in the increased yields. In a table comparing the yield figures of the Bangelan seedling offspring over 9 to 19 years, 11 gave more, generally up to 65 per cent more than average Robusta. The offspring of R.124 and 124.01 used for stocks were 5.9 per cent below the average yield. In comparing the yields of the various fields, Ferwerda used what he called the "production index", by which term he meant the proportion of the yield from a certain field or tree to an average field or tree.

The "production index" can be explained most easily by referring to another crop, rubber, for which a similar method has been in use for some time. When a superior rubber tree was studied, for instance a tree with a very high latex yield at Pasir Waringin, its yields were expressed not only

in the actual quantity of rubber obtained, but also by comparing it with the average yield for all the trees in the field. The figure thus calculated was called the "coefficient of superiority", since it indicated the extent of superiority of the tree to the average trees surrounding it and thus living under comparable external conditions. If a field had been planted on poor soil, a tree showing a good individual yield was of higher value than a tree on fertile land with the same absolute production surrounded by trees giving a higher average yield than the former tree. In this way the influence of external conditions was eliminated, and thus the "coefficient of superiority" brings out more clearly the intrinsic value of the high yielder.

In the case of the coffee production figures for the Bangelan fields, the same principle is applied to yields instead of to trees. Not only is their situation different, but also the periods which they cover for the various plots are still more different; and it may affect greatly the average for a field if a year of crop failure is included in the series for which the average is calculated. The fields surrounding the plots planted with seedling families were considered by Ferwerda as representing average estate Robusta, and thus his Production Index may be considered a measure for the superiority of his families and clones over ordinary plantings.

With other kinds of the Robusta group the same methods for improving the material have been used. C. quillou gave excellent results at Bangelan, and when these data were revealed in 1910-1915, many estates tried this kind, although it proved deceptive in many places. At Bangelan itself C. quillou was very productive. Q.Bgn.121 gave averages ranging from 48 to 67 per cent over 19 years, higher than ordinary Robusta (Ferwerda 1935, Table I, p. 12). C. quillou has formed vigorous hybrids with C. robusta.

The Robusta as R.Bgn.124 and 124.01 were found to be among the best plants for use as stock for grafting. R.Bgn.124 was originally chosen for its vigor, since it was the most vigorous tree at Bangelan (see Jaarboek 1907, p. 197). The seedlings of 124.01 were favorably reported as early as 1916 (Cramer 1916c, p. 402) and recommended for stocks in 1927 (Cramer 1927b, p. 1252). R.Bgn. 124.01 maintained a steady popularity for its vigor and its high resistance to nematodes. In an extensive experiment in which grafts of various hybrids were tested on various stocks, those on R.Bgn.124.01 also showed excellent growth (Cramer 1924a, p. 76).

In the beginning C. ugandae was considered as promising as C. robusta (Cramer 1908d, p. 733) and produced good results in a wet climate like Buitenzorg (van Helten 1911, p. 715). It hybridized easily with robustoid and other kinds of coffee. In 1912 apparent hybrids of C. ugandae and C. robusta were found in Bangelan among C. ugandae seedlings and used for further selection (Cramer 1927a, p. 88). In the comparison by Ferwerda, (Ferwerda 1935, Table 1) four C. ugandae strains gave figures about equal to those for the improved Robusta.

In the beginning C. canephora attracted the attention of Wurth, who thought it might play an important role, second only to Robusta (Hille Ris Lambers 1932, p. 7), but it did not fulfill its promise. Bangelan developed several strains of various introduced forms, but none came to the forefront, probably because C. canephora is apparently rather susceptible to leaf disease. Only one seedling family, Canephora Bgn.Mad.3, developed from a tree introduced from Madagascar, was of any importance as a good grafting stock. In its earlier period, 1901-1929, annual reports on such results were published regularly, but since 1929 no more have appeared; and after Ferwerda's article of 1935 no information on mother trees, seedling families, or clones has been published. This circumstance is in contrast with the situation at Soember Asin, where Hille Ris Lambers frequently reported the advancement of the work. A note of s'Jacob and Hille Ris Lambers (1938, p. 41), pointed out that hybridizing with liberoid and excelsoid coffees had been transferred to Bangelan.

IMPROVEMENT BY PRIVATE INSTITUTES

The Malang Institute conducted much improvement work with Robusta, mostly at its selection station at Soember Asin, situated in the Robusta belt. It began in 1906 with improvement experiments on C. liberica (Hille Ris Lambers 1932, p. 3). In 1908, when Robusta became popular, and hybrids also seemed more promising, C. liberica was given up and a new start made with Robusta. Mother trees of it were selected on estates, and seedlings from them planted out. In 1910-1915 other kinds were added. In 1922 other mother trees were selected, and plots of grafted trees were established. In 1926 Hille Ris Lambers (1932, p. 36) started his selection experiments, which comprised many artificial crosses of Robusta types. Some apparently contained "blood" of other species, for example, SA.109 appeared to have some C. quillou in it and was also qualitatively parallel to R.Bgn.124.01, but very susceptible to berry borer. The fruit of SA.24 had a bronze hue, a fact that indicated C. canephora relationship (Hille Ris Lambers, 1932, p. 34); and like this last species the clone was susceptible to leaf disease (Hille Ris Lambers 1938, p. 187). Later on SA.13, SA.34, and SA.158 became popular among planters (Vraagbaak 1941, p. 125).

The research institute in Djember conducted its selection experiments at Kaliwining, only 50 m.

above sea level, thus in the low country belt. The station was first intended as a testing plot and for seed production (Ultee 1922, p. 6). A large number of plots, planted in 1914-1917 with seedlings of trees from Bangelan and estates, served in 1922 for starting their Robusta selection. Arisz (1926, p. 11) chose the two most productive fields for this work, one containing seedlings of Moenboel, dating from 1914, the other containing seedlings of Bajoe Lor Grootboon dating from 1915. This latter planting descended from a tree with large berries, one of the first Robusta trees introduced (Ultee 1922, p. 12). Although some trees in this field did not maintain this character, the average tree gave larger berries and beans than ordinary Robusta at that low altitude (Ultee 1922, p. 22). Trees in these fields were chosen and multiplied by grafting, and by seed obtained through self-pollination. These plots date from 1925 to 1926. These mother trees formed the origin of the following families: Moembole 3.04, BP.39, and BP.42. A large experimental plot was also laid out on Kendang Lemboe Estate, which comprised seedling families, from self-pollinated seed, and grafts of various BP. numbers and also grafts of many Bangelan clones of "Robusta", "Quillou", "Canephora", and "Ugandae" coffees as well as "Congusta" numbers. It was described in 1929 by Schweizer (1925, p. 1426) with a map giving the full inventory. As has already been noted, in later years the Besuki Institute started comparative tests with seedling families from various clones.

While the stations mentioned included material from the outside in their experiments, in 1912 the Research Institute for Central Java started an independent scheme for Robusta selection on the Banaran estate (van Hall 1912, p. 5) with grafts and seedlings from the estate. After the experiments had been carried on for several years (van Hall 1912, 1914, and 1917), Bally (1920a, p. 8) took over and reviewed the data obtained. Size and weight of the beans in a clone were fairly independent of external conditions. The quantity produced was so dependent on factors difficult to control that grafts seemed to be the solution, and a further project on this basis was described. In 1926 the Malang Institute took over the work, and Hille Ris Lambers filled in a gap by including in the comparisons not only material from the estate itself, but also clones and seedlings from Bangelan and Soember Asin (Hille Ris Lambers 1931b, p. 103). The work has not yet resulted in putting the improved material on the market, and for a dozen years nothing further has been published on it.

All the selection stations adopted the system numbering started at Bangelan (Gandrup 1930, p. 301). In later years some of the numbers given by the breeders to the Bangelan types have been changed. A good concise summary of selection in the various stations was published in 1938 by van Hall (1938, p. 87).

SELECTION ON ESTATES AND THE NURSERY

Apart from the plant improvement experiments at the research institutes, similar work was also carried on estates where it has been a practice of long standing in the nurseries to use seed taken from trees with an outstanding yield and with other desirable characteristics, e.g., freedom from diseases. Ultee (1932b, p. 304) drew attention to this almost unconscious selection which must have been applied for many years before the research stations began their organized selection experiments, and which probably is still being carried on. The estates have even introduced many new kinds. When improvement of plantings by the grafting of poorer yielders is started, the graftwood is also frequently taken from the estate's mother trees chosen for their good performance and therefore considered to have proved themselves especially adapted to and most suitable for the estate's peculiar conditions. In contributions of planters to the discussion of the problem of improvement and degeneration, cases were often cited in which estates used their own material for establishing new plantings or for selective grafting. In de Stoppelaar's lecture (1936, p. 1163) several instances were mentioned.

The manner of organizing an estate selection was described by Stadt (1930a, p. 495) who originally chose 234 trees on his estate. The berries of these trees were collected separately to check their yield. After an attack of branch borer the number was reduced to 72 and later to only half that number. Poor yielders in the plantings were marked with a coloring, and the poorest ones removed, whereas the best yielders were marked with another color. This census was repeated for several years. Specially trained mandors or native foremen chose mother trees from among the trees that had received a good mark every year. In his lecture Ultee (1932b, p. 305) did not encourage the use of material obtained in this way, since the method was apparently not sufficient. The material offered by the stations specializing in this kind of work was more readily checked, and its history known over a long period, thus giving a better guarantee of its intrinsic value.

Another form of plant improvement in coffee has been nursery selection. In this term the word "selection" is not used for improvement extending over several generations and aiming at the attainment of improved families or clones, but simply a grading of the plants in the nursery, rejecting the poorer grades and putting out only selected plants in the fields. The case was known of plants trimmed to be used as stumps, of which more than 30 per cent were lost by such drastic treatment.

Those remaining gave a planting which was the pride of the estate (Schweizer 1934, p. 175). In the discussion after de Stoppelaar's lecture on degeneration, de Ligt mentioned that formerly all the plants from the nurseries were frequently transplanted and cited a case of an estate where a severe nursery selection was applied with the result that it was the only one to give a good yield that year among all the estates in the region.

In practice, nursery selection has been generally applied for discarding diseased, damaged, and otherwise abnormal plants, especially plants with bent roots. It was thought that the latter were rejected for good reasons, as frequently they did not withstand drought. Reydon (1926, p. 350) described arabian plants with bent roots that had been put out and died in the first dry season after flourishing at first, since the bent taproot had not penetrated to a sufficient depth. A study of plants with bent or crooked roots or "pig tails", as the planters called them, by van der Veen (1938a, p. 256) did not confirm the planters' objection to them. It was found that in the station of the Djember Institute at Kaliwining the nurseries on the stiff clay there always had half or more of their plants with bent roots as a result of soil conditions. Since those with bent roots had to be used frequently, it was found that the older plants were not backward by comparison with those with straight roots. An experiment in which both classes of plants were grown in alternating rows and compared, together with the experience with seedlings from Kaliwining on estates where they were planted, further confirmed this fact. Observations on old, well-bearing Robusta trees have shown that they often have no distinctly well developed taproot. It has seemed therefore, more important to give attention to the appearance of the part of the plant above the soil than to that of the root.

It may be possible that plants of a much higher intrinsic value can be obtained by a more rational selection. A preliminary experiment at Soember Asin gave promising results, and since then planned experiments were started in which a comparison was to be made between plants for which height and girth were measured individually. Some abnormal forms, such as the plants with crinkled leaves, germinated slowly so that the time of germination could be taken into account in the sorting, and some results probably could be obtained at this early state (s'Jacob & Hille Ris Lambers 1938, p. 43). Gandrup (1934c, p. 501) found that various methods of selection at the kepelan stage or with cotyledons only did not give indications on the development of the root system.

CHAPTER 21
THE EFFECT OF SELECTION ON ROBUSTA

SELECTION AND SIZE OF BEAN

When we attempt to estimate the progress resulting from the laborious work on the improvement of Robusta planting material, the results may be expected to be especially conspicuous in vegetative offspring, since the connection with the mother tree is more direct. The first point to consider is, how superior are the mother trees to the average tree? The second is, to what extent may this superiority be transmitted to the offspring? A third question is, to which characteristics of practical importance does it relate?

The last point may be answered first. The main purpose of breeding experiments is always to increase the yielding capacity. Increasing disease resistance is essentially a part of the first problem, since its effect will be revealed in higher and more stable production. The external factors affecting the size of the crop are so complicated with a seed crop that it is difficult to distinguish clearly the internal factor, the capacity of the plant to produce, from all the others. It is recognized that his internal factor itself is extremely complex. In regard to qualitative improvement the problem is much simpler. Questions such as taste and flavor, so dependent on subjective judgment, can be omitted and attention limited to the size of the bean. This is an individual characteristic. Some trees give beans of a large average size, but in others the average bean is small, and this characteristic is stable. Bally (1920a, p. 8) compared figures for the mother trees at Banaran, found in 1913, with data collected in 1919, and concluded that the trees showing a large average bean in 1913 also produced the largest beans in 1919 and that the trees giving small beans in 1913 produced the small beans in 1919.

The size of the bean is a very important detail for some regions of Indonesia, such as the low plains of Besuki where the external conditions cause the tree to produce a small beaned, market product. At Kaliwining, at 50 m. above sea level, the well known large beaned BP.42 gave much smaller beans than on an estate at an altitude of 500 m. where the beans were 16 per cent longer and 13 per cent broader (Schweizer 1936a, p. 655). This factor may influence the bean size to such an extent that the crop is wholly, or to a great degree, composed of "kried bean" which is the smallest grade of beans, and therefore under the bean size required for Fair Average Quality, a circumstance that makes it unfit for sale as export quality. The problem then becomes, what can be done to produce large beans? This problem may be solved by choosing large beaned types for planting material, since the large bean characteristic is to a certain extent hereditary, not only for clones, but also in generative multiplication, Schweizer (1936a, p. 654) studied the heredity of this characteristic and in the first generation obtained by selection an increase of 0.7 mm., in the second generation 1.5 mm., and in the third 2.4 mm.; the heredity of the characteristic was further confirmed by Hille Ris Lambers (1936a, p. 976) who made a good many crossings of Robusta types to combine large beans with high yield and succeeded in obtaining considerable improvement in the size of the bean. The heredity of the size of the bean appears clearly in crosses in which large beaned trees such as BP.42, SA.94, and SA.172 participate (Ibid; 1937a, p. 990). In later crossings very striking results have been obtained. One seedling of the cross BP.42 x SA.94 gave beans averaging 9.4 g., a surprisingly high weight for Robusta (Ibid., 1941, p. 1530, see photograph).

The use of such material on estates must show itself in the practical results, and Schweizer (1936a, p. 661) cited a case in point. In Besuki some estates put out 30,000 grafts in their fields annually to improve the average bean size for the estate, and applied field grafting using large-beaned clones. The results forced an estate in the low plains to rearrange its factory so that the large and small berries could be separated in the beginning for separate treatment. From the first the product had an average length of 8.5 mm., while for the small ones the average was 7.3 mm.

Such a case taken from practice makes it clear that planting material is now available with much larger beans than the older forms. Its gradual spread in the planting industry would result in an improvement of the market product.

EFFECT ON PRODUCTIVITY IN GENERAL

Although doubts have sometimes been expressed as to the effect of selection on the yields of Robusta, the data in the following sections reveal that there has been distinct progress.

Witce is said (Neculom 1940, p. 1600) to have expected that yields per acre would increase by 15 per cent from selection and by 50 per cent from general improvement of the technique. However, the only statement by Witce on this point (1924, p. 1539) was to the contrary. He cited similar figures for crops in Europe, but he expected a much better showing for the effect of coffee selection in Indonesia, where it might perhaps rank first as a factor in improvement.

When the yield capacity is studied, the starting point must be the behavior of the individual

trees in a field, preferably over a period of many years, since crops may vary a great deal from one year to the other and since the individual trees may react differently to weather factors. As early as 1919-1920 individual yields were determined for *C. arabica* by Anstead (1921, p. 338). For *C. robusta* this problem was studied by the Malang Research Institute, which collected and published figures on it for a period of the 4 years of 1933 to 1936. The census comprised 400 Robusta trees yielding an average of 15 piculs per bahoe or 13.5 q./ha. They were seedlings of Robusta SA.7, dating from 1927. After determining the average yield for 400 trees, the difference in yield with this average was calculated for each tree and expressed in percentage of the average yield.

The values thus found were used for classifying the trees according to yield. This was done for the successive years and for the whole 4 year period. The conclusion was as follows: (1) In one cropping year some of the trees yielded so well that the average for all the trees was increased. (2) The number of trees giving a high or a very high yield was smaller for several successive years than for one cropping year, a fact which indicated that some good yielders had drops in yield in some years. (3) The number of low yielders was smaller over a 4 year period than for one cropping year, a fact which showed that some trees in the class of low productivity gave better yields some years. (4) A small number of trees produced well or very well in successive years.

The coefficient of variability was as follows in the four years: 63, 62, 62, 62, and 69; and 49 for the whole period. This reduction for the whole period was of course, caused by the alternating yields of many trees. If the contribution of the successive classes to the total yield was calculated, it was found that the upper decile of trees gave 20 per cent of the yields, and that the upper half gave 70 per cent of the yield (Snoep 1937, p. 139). It is interesting to note that for *Hevea brasiliensis* a similar proportion for the production of the upper half of the highest yielders was found (Cramer 1919-1920, p. A.52), and the same was true for tea (Wellensiek 1934, p. 894). Snoep calculated that by replacing the lowest fifth of his Robusta trees in terms of yielding capacity, with trees giving yields similar to those of the upper decile, the total yield would be increased by a third. In the same manner a planting composed entirely of trees belonging to the best class, the upper decile giving the double yield, would also give twice the crop of the unselected trees.

Special attention was given to the annual variation of the tree yields. Of these 11 per cent gave only slight variations in their annual crop, and these were mainly in the lower yield classes. Two per cent, however, belonged to the classes with highest yields. For another 12,8 per cent of the trees the annual yields showed only regular slight variations, and for 21.4 per cent large variations. The balance varied irregularly in the yield (54.7 per cent; loc. cit., p.141).

The variations in tree production with grafts were also studied. For the calculations, 6 rows of 9 trees served, each row representing one clone. The figures were taken for a 3 year period, 1934 to 1936. In some years the clones showed a high variability. For instance Sa.114 showed a coefficient of 68.3 in 1936. But, for the whole period the coefficient of variability was 10.4 to 27.2, much lower than for the seedlings (Snoep 1937, p. 142).

It is a point of considerable importance that with the study of the individual yields a certain number of trees were regularly found in the top classes with respect to yield (see also Hille Ris Lambers 1931a, p. 688). The ideal tree would be the one which is fairly independent of external conditions affecting the success of its crop and which would, even under unfavorable circumstances, produce a good crop. Citing examples from other crops, Cramer (1923-4, p. 173; 1927a, p. 88) claimed that there was every reason to expect that clones doing well under highly variant conditions in different localities and in different years could be found and that such universal clones were preferable to those with capricious high and low yields. The actual results of selection indicate that such clones exist.

However, when an outstanding high yielder was found, it has not yet been possible to predict how its offspring would behave in this respect. Schweizer (1925, p. 1426) distinguished 4 possibilities which he found in his experiments in the test plots at Kendeng Lemboe: (a) Trees may be more suitable for vegetative multiplication than as mother trees for seed production (BP.25). (b) Trees could be more suitable as seed producer for generative multiplication than as mother trees for developing clones (BP.42). (c) Some trees were not of highest excellence either as mothers for seedlings families or as starting points for a clone (BP.4). (d) Some trees were excellent for vegetative as well as for generative multiplication and represented a considerable improvement for the planting in every respect (BP.39, BP.56).

Other cases have been cited by Gandrup (1935b, p. 380). Robusta SA.109 proved to be a good yielder as well as being selected for a mother tree. The seedling family derived from it grew vigorously than the seedlings, and they yielded well. Robusta Bgn.105 was a very good yielder as a mother tree and produced vigorous seedlings that yielded well, but its grafts yielded poorly. Hille Ris Lambers (1931a, p. 690) mentioned the case of Robusta SA.75 b, a mother tree whose grafts were better than those of the original mother tree.

The disappointing results which superior mother trees often gave when tested as clones were attributed to two causes (Hille Ris Lambers, 1935c, p. 357, 1937a, p. 985). In the first place, he found that the superiority of the mother tree could be due to external conditions; and it is, of course, lost when the clone is no longer subject to these same conditions. A second factor was that the graft reproduced the mother tree in all its stages. It was early disclosed that out of the clones developed from good mother trees only 5 per cent were really good ones. Therefore he selected the mother trees for clones in young fields. He had found that grafts began by repeating the youthful stage of the mother tree, a procedure which was deceptive in the case of Robusta.

Only a few older clones showed a harmonious transition from primary to secondary branches and from these to wild wood enabling the tree to increase its annual crop regularly. Good examples of this were most clones of Congusta and Robusta such as SA.24, SA.109, BP.39, and Bgn.83.03. Generally, however, the grafts from a tree chosen in an old field showed a regression in their development caused by the dying of the primary branches, frequently as a consequence of excessively heavy bearing and the late formation of wild branches.

When the yield of a mother tree and of grafts made from it were compared, the difficulty was that grafts were always much younger than the mother tree. At Soember Asin a Robusta tree was considered adult when 9 to 14 years old. The yields of 11 clones at Soember Asin were compared with those of the mother trees in 11 cropping years. The average for 8 cropping years, thus comprising some belonging to the early stage, and the averages for the last 3 cropping years were compared and expressed in the percentage of the average yield of the mother trees. The first series of 8 years for the clones, fluctuated around an average of 44.9 per cent, with 26.2 per cent and 69.4 per cent as extremes, while for the last 3 years the percentages were: average, 73.7 per cent, with 48.7 per cent and 110.5 per cent as extremes. This indicated that at this older age the average yield of the clones sometimes surpassed that of the mother tree. For some well known clones it was still lower: for SA.13, it was 50.6 per cent; 84 per cent for SA.24, and 60.5 per cent for SA.109. It is interesting that for the whole of the clones the average yield per annum was 18.3 q./ha. (p. 987) in the last 3 years of the period.

Hille Ris Lambers (1941, p. 1524) later gave figures for the yields of mother trees and of the grafts derived from them. When the first 6 cropping years were omitted in order to make them more comparable with the mother trees at a certain age, the average proportion of the yield of the eleven clones, compared with that of the mother trees, was 79.8 per cent. Thus it was nearly comparable. For most of the well known SA. clones the figures were on the lower side: SA.7 gave 65 per cent; SA.13 gave 51; SA.24 gave 88; and SA.56 gave 50. With SA.74, the proportion was very high, for grafts gave 166 per cent of the yield of the mother tree.

EFFECT ON YIELD OF SEEDLINGS

When the results of selection are studied in Robusta seedlings, the main point to consider is the increase of the yielding capacity of the trees under the varying conditions of different estates. Extensive experiments with seedling families were started by the Besuki Research Institute which used some older testing plots in single units. A new series of comparative tests in multiple units with seedling families raised from clonal seed of some of the best clones was initiated. The first results, after 3 cropping years, were published in 1938 (s'Jacob, 1938a, p. 58) together with some yield figures for the older testing fields. These latter plots were rather small in many instances, and the figures calculated per hectare have to be considered with some reservations (s'Jacob, loc. cit., p. 61). On Kendeng Lemboe the BP. families 4, 25, 42, and 56 gave 13 to 14 q./ha. averages taken from 11 cropping years. BP.39, with 14.6 q., comes out at the top. At Malang Sari BP.39 with q./ha. and BP.42 with 18 q./ha. were the best of 4 clones in averages taken over a period of a decade. At Sampar BP.25 led in an average of 6 cropping years with 15.6 q./ha., BP.42 giving 14 q./ha. only slightly behind, but BP.39 and BP.56, both with 11.8 q./ha. were somewhat lower. In the second series one estate with a rather moist climate showed considerably lower figures, averages over three years: the best family, BP.42, gave only 4.7 q./ha., and a mixture of good SA. families gave only 3.6 q./ha. At Lidjen, in the first series of estates, in a very wet climate, the averages for 7 years were found to be: BP.39, 1.6 q./ha.; BP.42, 6 q./ha.; BP.56, 4.4 q./ha. At Kaliwining the average over 11 cropping years were: BP.39, 12.2 q./ha.; BP.42, 16.7 q./ha.; BP.56, 12.2 q./ha.; BP.46 although generally not one of the outstanding numbers, 20.2 q./ha. It appeared that BP.42 was one of the best and gave high yields even under conditions unfavorable for Robusta. The more favorable the conditions, the less the differences became. The figures cited also gave an idea of the comparatively good crops Robusta produced in that part of Java.

In later years, 20 more systematic testing plots were started. The oldest ones dated from 1931-1932. Particulars about every testing field were given with yields obtained. In a discussion of the results attention was drawn to the fact that the family BP.42 did well in nearly all testing

fields. In 5 cases out of 7 it was significantly better than all others, and in 2 it was at the top, although the figure was not considered significant. In no case was its yield significantly smaller. From these facts it could be concluded that one family, BP.42, under highly varying conditions, did very well and that the risk that it would give a disappointing performance in comparison with other families was slight.

The family BP.4 commanded attention for its growing qualities. Generally it was a good producer, but not in such universal terms as BP.42. It was susceptible to the branch borer. As a seedling another one, BP.24, was much less sensitive to this pest than as a graft. It was less stable but seemed well adapted to very dry regions, and BP.39, although less universal in appeal than BP.42, approached its qualities. For one thing, it showed the highest resistance to branch borer. On other numbers the opinion was less definite: BP.56 was not considered very promising; SA.56, not frequently included, might have come near to BP.42 and SA.24 did well in several places, but was somewhat behind SA.56; SA.34 was desirable only a higher level, and an objection to it on the lower estates was the small bean; the same applied to SA.109, but here too the yield was disappointing. Although results of SA.158 were only known for one year, its merits deserved special mention for yield and excellent appearance.

The Bangelan families were disappointing. The absolute yield figures of the families just mentioned were often rather high. For instance, yields for 3 cropping years at Kalisanen averaged 13.4 q./ha. for BP.42, and 11.8 q./ha. for SA.56, for the best families. For several others the average was just over 10 q./ha. On another estate the Robusta was planted mixed with rubber, but rubber grew so slowly that coffee could be considered an unmixed planting in the first 3 cropping years. Still the yields reached only 3.4 q./ha. At the end, the most practical scheme for a family test was described as follows: plantings to be made with rows of the various families of 20 to 30 trees, in 10 to 15 replications, and not more than 10 different families to be compared.

A similar review of comparative tests for families, and also for clones, was made by Snoop (1936b, p. 219) but the experiments had few or no additional units, and the period of 2 or 3 years for which the crop figures were collected was generally short. The differences between the families were not very striking, and no universally high yielding families were found. Some Bangelan families are equal to or under the figures for SA. families. In several cases BP.39 and BP.56 did fairly well. Average yields were recorded from Kebon Doeren, of 8.3 and 8.9 q./ha. as against 6.2 to 9.5 q./ha. for some of the well known SA. numbers such as 34, 56, 85, and 158. In another case Bgn. numbers 105.04 and 124.01 did better, with 7.1 and 6.3 q./ha., than did BP. numbers 42 with 5.5 q./ha. and 39 with 4.1 q./ha.

From the figures published to date it is difficult to ascertain the superiority of families known at present over ordinary material, since no figures on the latter are appended for comparison. The yield figures for some of the Besuki testing fields were high, but the average yields for the estates where they were situated were also high, probably higher than the Malang figures. For this last province the yield figures did not seem to surpass ordinary Robusta to a very high degree. It seemed doubtful whether a coefficient of superiority of more than 1.5 was reached, and this would mean that in such cases the improved material had a 50 per cent greater productivity than the ordinary fields. Coolhaas cited a much higher figure (1941, p. 63) when he stated that the difference in productive capacity between seeds was more than 300 per cent. Another striking surplus yield for seedling families was cited by van der Veen (1941, p. 278). He pointed out that an estate might give a satisfactory crop for 2 or more consecutive years if weather conditions were favorable. When an excessively heavy crop was produced, in the following year, even with favorable conditions for the flowering and ripening of the fruit, the crop would be small. Such a heavy crop would have to be considered then as having surpassed the optimum yield level which was reached in the years of consecutive good crops. The yield level would be different for the individual trees, for the various clones, and for the seedling families.

Van der Veen pointed out with graphs that in a test of various seedling families at Kalisanen, each present in 10 units during 5 cropping years, the optimum yield levels for the families BP.42 and SA.56 were higher than for the families SA.13 and SA.34, while SA. mixed seedlings showed a much lower optimum yield level. These first 2 families gave an average of about 150 per cent more than SA. mixed seedlings during the lustrum. Although the author did not say so, it seemed probable that these last mixed seedlings were already better than ordinary unselected seedlings.

The methods of producing improved Robusta seed on a commercial scale from clones which were known to have a good progeny were described by s'Jacob & Hille Ris Lambers (1938, p. 40). The seed producing field could be planted simply with two clones the so-called diclonal seed gardens. The objection was that if better combinations were subsequently found the field was valueless for seed production. Another system was to lay out isolated monoclonal fields and pollinate them artificial-ly with the desired pollen parent with some such device as a "flit" gun. The newest system was the

interplanting of a large monoclonal block at the four corners with four different clones for pollination, while the central part, being monoclonal, remained available for artificial pollination. The seed of such plantings were often called "legitimate seed", a term that should be avoided, since it conveys the idea that one is absolutely sure of the parents. This can not be the case, although the seed are formed in large measure by cross pollination. It is only very rarely that clones are absolutely and perfectly self-incompatible. Thus there is always the possibility that a small percentage of the seed from these gardens may have been selfed, although the seed may have been called the result of a cross of "legitimate" nature.

EFFECT ON YIELD OF GRAFTS

With grafts the performance of offspring may be considered as more directly connected with the mother tree, and thus it may be expected that the superiority of the mother may be maintained better in the offspring. It seemed clear that if the starting point was with the best trees in the province of a research institute, the superiority of the latter would still be considerably higher than that found in the high producing 10 per cent of trees (Sneep 1937, p. 139), which gave double the average yield over a 4 year period. Two per cent of the total number of trees were shown to be within this group of 10 per cent, and at the same time they were consistently high yielders (Sneep, loc. cit., p. 141). It seems not too bold to take it for granted that the trees from which clones were selected produced treble the yield of the average trees.

No one has calculated the real coefficient of superiority of the various clones, and there are no data for such calculations. Sneep's search for superior trees may be compared with a hunt, while at present the trees used for developing clones were found by individual hunters. Not all the trees tried for grafting were kept. Gandrup (1934a, p. 223) stated that good yielding mother trees were sometimes disappointing as grafts and estimated that only 3 to 5 per cent gave satisfaction as a clone. At Soember Asin 200 mother trees produced up to that time only 5 clones which had been found to be entirely reliable, but this number still might have been increased. The Besuki Institute obtained only 4 or 5 clones out of 60 or 70 mother trees. At Bangelan an original number of about 300 trees resulted in a still smaller number of clones. During a visit of planters to Bangelan, Cramer (1923, p. 1577) showed grafts of Robusta Bgn.105, one of the best mother trees at Bangelan, which gave poor results, while its seedling offspring was very good. Only a few clones remained from the selection experiments at Banaran. At Tretes Panggoeng 1000 mother trees were tried, but only a small number was kept. Gandrup (1937, p. 418) estimated that from hundreds of clones tried at Soember Asin and elsewhere, only a very few remained which came up to expectations, and among these the number of clones suitable for budding old trees in the fields was still smaller.

Under these circumstances one would expect that the clones of Robusta now available for the planter would show not only an accumulation of desirable characteristics in many respects, especially in relation to resistance to disease, but also stable yields of more than double the average tree. To a question as to whether there were definite figures available on grafted fields, their yield, their growth, susceptibility to diseases, etc., Ferwerda (1935a, p. 433) replied in 1935 that such figures were not yet available, since clonal plantings under good conditions were not yet in full production for a sufficiently long period. Although not yet under optimum conditions in this respect, some clones gave double the yield of average seedling plantings. The growth was as good, if not better, than that of seedlings, and the first data were considered promising.

Since then data have been published on the results of test plots of clones on estates, but thus far the figures do not show the considerable improvement one would expect after the rigid selection through which their mother trees have passed. In 1939 Sneep (1939, p. 652) published some results of these experiments which showed SA.13 as the most productive, while SA.34, 56, 85, and 109 together formed the second group, to which SA.7 and 24 could be added, although they were more available in their yields in the various plots. The three well known clones of the Besuki Institute, BP.42, 39, and Moemb.III.04, also belonged to the first group. Of the Bangelan clones the older ones were not satisfactory. Among the newer ones that yielded well, Bgn.300 was considered equal to the best BP. and SA. clones. Two years later Sneep (1941a, p. 399) gave further results on the clone testing plots. These plots were divided into the elder sets, old preliminary row tests at Soember Asin and on estates, and more modern testing fields. One of the positive results from all these figures was that there were clones which in most of these tests gave the highest or nearly the highest yields. Since the testing fields had been laid out under highly variant conditions of soil and climate, there was a strong probability that these clones were only slightly sensitive to these variations in conditions and might be called "universal".

The periods during which the various sets of clones have been tested vary. The elder test plots had been observed for 6 to 12 years, the more recent ones only 2 to 3 years. One clone may reach full productivity at a later age than others, mainly in relation to its growth, but it has been sat-

isfactorily proved that a clone which excels in the first 2 or 3 cropping years will also belong to the best yielders later on, especially when it shows up very well in the older testing plots.

Applying these principles, Sneeep (1941a, p. 406) then arrived at the following list of recommended robustoid clones for the province of the Malang Institute with the percentages in which they should be used:

| | | |
|--------------|-------|----------|
| EP.42 | 25-30 | per cent |
| SA.13 | 25-30 | per cent |
| EP.39 | 15 | per cent |
| Mocmb.III.04 | 10-15 | per cent |
| SA.34 | 10 | per cent |
| SA.56 | 10 | per cent |
| Bgn.300 | 10 | per cent |

The two first clones were among the universally good ones, and they were also among the best known. SA.34 and 56 were high yielders at Soember Asin, but in other regions were not so good. Although experience with EP.39 was more limited, it was always favorable. With Mocmbeel III.04 this was still more true, and practical experience was favorable. The same could be said of Bgn.300, which was only represented in 4 sets, in 2 of which it did as well as EP.42 and SA.13. Some other clones of SA and BO were mentioned as worthy of attention, e.g., SA.158 and EP.4. A fairly large variety of Bgn. clones was included in the tests, but excepting Bgn.300 it was difficult to find a clone among them which was among the best in several places. Bgn.2.09 and 105.04 are mentioned with some other ones.

The various clones have been further classified according to the size of the bean, determined by dividing them by sieving in fractions of larger than 8 mm., 7 to 8 mm., and so on, down to a group smaller than 6 mm. The EP. numbers made a good showing in this order of merit. Sa.36, Mocmbeel III.04, SA.13, and SA.109 were at the bottom of the list, all with about 60 per cent of beans from 6.5 to 8 mm. and 14 to 17 per cent 6 to 6.5 mm. The data were not compared with figures for plantings of average Robusta under equal conditions, but the absolute figures, calculated in q./ha. may give some idea of the yields. For SA.13 in testing plots, yields for the two to three cropping years averaged 15.3 and 4.4. For EP.42 the averages were 15.8 to 10.2, with 4.2 on the same dry estate for which the low yield of SA.13 was just mentioned. There Bgn.300 gave an average of 5.2 against 3.7 to 1.2 in the other places. From such figures one cannot conclude that the clones are far superior to ordinary seedlings, certainly not with a coefficient of superiority of more than 2.

The tables also gave some data on Congusta clones in the first cropping years. On 2 estates these hybrids compared favorably with the Robusta clones. Both estates were at a certain altitude and with a moist or fairly moist climate. On the 4 other drier estates the comparison was in favor of the highest yielding Robusta clones.

The suitability of various clones for use as branch grafts is also a problem. A field at Soember Asin was established with unselected branch wood in 1933. Most clones developed into fan branches. After 4 cropping years the order of merit of the 8 best clones was: EP.42, SA.109, TrP.21, SA.34, Mocmb.III.04, Bgn.105.04, and SA.13. For vigor and rejuvenative power TrP.21 was still unsurpassed as a branch graft. The yield was satisfactory, but the bean was very small. The EP. numbers had a tendency to develop excessively upright fans, but by proper selection of the grafting wood this could be corrected. There seemed to be a later tendency among planters to use whip branches, and all the recommended clones could be used very well for this purpose (Sneeep, 1941a, p. 406).

In one of the most recent articles Ferwerda (1941, p. 561) stated that for "newer" clones from Bangelan, when mixed to facilitate cross pollination, average yields of 15 q./ha. were by no means impossible. He cited such newer clones as Bgn.300, 325, 340, 371, and 372. Four of these clones were old Bangelan clones under a new name. Only Bgn.371 had been added recently to the list. To avoid confusion and to facilitate comparison with the data, a list is given here with the old names under which the clones were distributed prior to 1930 and under which they had been kept in the Economic Garden at Buitenzorg, and the names Ferwerda gave them in 1935 (Ferwerda 1935, p. 1):

| Old name | New name | Old name | New name |
|-----------|----------|----------|----------|
| Bg.L.25 | 202 | Sa.1.09 | 300 |
| K.G.2 | 208 | S.T.3.06 | 325 |
| K.G.3 | 209 | S.T.4.05 | 340 |
| Bg.L.2.01 | 201-01 | Bg.C.1 | 372 |

This matter is of more general interest, and therefore the history of this material is inserted here. When I took over Bangelan in 1915, I found that in the selection experiments with Robusta there, only the original trees and their progeny had been used. The numbers of these introduced trees was only 24. This seemed to be too narrow a basis for improvement. The private estates had introduced hundreds of Robusta plants, and thus it seemed reasonable to try to broaden the basis by adding the best from this outside material, more numerous and thus richer in variations, to the collections of Bangelan. Seed of valuable Robusta trees chosen on estates were taken to Bangelan and used for laying out small plots. Afterwards in these plots the best trees were again chosen and used for making clones which were planted in the clone museum. They were kept under the name of the estate which their mothers came.

It is a striking fact that none of the clones renamed and mentioned by Ferwerda as the most promising ones came from the material descending from the 24 Robusta trees originally introduced at Bangelan. It shows clearly the danger of starting selection on a basis that is too narrow.

CHAPTER 22
VARIOUS SPECIES

In addition to the three main kinds of commercial importance and the species allied to them, there are other *Coffeas* which have not been used for commercial purposes but which have been introduced into Indonesia for study as possible material for improvement. They will be enumerated here.

COFFEA STENOPHYLLA

C. stenophylla is indigenous in Sierra Leone and French Guinea. In Sierra Leone it occurs wild at an altitude of 190-550 m., where it is also cultivated by the native population. The product is exported as "highland coffee". Chevalier (1929, p. 8) noted that C. stenophylla was cultivated by the natives of Sierra Leone as early as about 1790, probably under the influence of Europeans who wanted to buy the product from them. The botanist G. Don noted that the seeds of C. stenophylla were roasted and considered superior to common coffee (Hieron, 1876, p. 172). In French Guinea the species was found wild at 400 to 700 m. altitude in the gallery forests along the rivers and in the large forests in moist places, especially in the region between 10° and 11° north and 15° and 16° west of Paris, with an annual rainfall of 1.5 to 3 m. Nearer the coast, at 300 m. altitude and with more rain, near Boké on the Rio Nuñez, it occurred only as a cultivated plant. The product was exported as Rio Nuñez Coffee (Chevalier 1905a, p. 1473).

The taste of roasted C. stenophylla was described as "exquisite". According to the natives, and, as well the French traders in Freetown, it was considered a superior flavor and sold there as "best Mocha" (Scott Elliot, 1893, p. 167). Van Romburgh (1903, p. 369) found the taste of Stenophylla good, that had been produced in the Cultuurtuin in Java. A small sample of the same origin was tasted by Cramer (1913, p. 620) who found it strong and slightly bitter, somewhat resembling Mokka coffee. A third opinion on a sample of C. stenophylla from the Cultuurtuin was less favorable (Jaarboek, 1906, p. 76). Samples received from a planter in Sierra Leone were submitted to several experts who observed that the beans were irregular in shape (Stennekes, 1898, p. 619).

The often praised flavor of the market product gives the species a certain practical attraction. Scott Elliot drew attention to the commercial potentialities, and in 1893 he sent some material to the Kew Gardens. In 1894 this institute introduced nine pounds of seed and planted part of them in its own hothouses, while the other seed were distributed to botanical gardens in British colonies and British India. The plants in Kew flowered as early as September 1895 and were described and illustrated by J. D. Hooker in the Botanical Magazine for 1896. The reports from the various gardens which planted this new kind experimentally are different and not too favorable (see Highland coffee of Sierra Leone, 1896).

Although at the end of the nineteenth century a serious attempt was made to introduce C. stenophylla into tropical agriculture, it seems to have been unable to get a place among the coffees produced on a large scale. Even in Sierra Leone itself the production did not seem to progress. Samples of C. stenophylla from there were examined in 1924 by the Imperial Institute and did not appear to have been cleaned or graded (Sampson, 1930, p. 233). Ukers (1935, p. 231) mentioned C. stenophylla from Sierra Leone as "a native growth; not a trade factor" in his list of the principal kinds of coffee grown in the world.

In the Cultuurtuin, C. stenophylla was introduced in 1896 from Kew, and in 1899 it was introduced from Singapore (see Cramer, 1908a, p. 403).

It was afterwards reintroduced from Aburi in 1914 and from Camayenne in 1915 (van Hall & van Helten, 1917, p. 48), but it never became popular among Indonesia planters. It has never even been tried for experimental planting, as far as is known, although its merits have been brought to the attention of planters on several occasions by articles in *Teysmannia* and in the planters' own periodicals such as the *Cultuurgids* (du Bois, 1901-1902, p. 136).

Coffea stenophylla is a shrub with a dense branching habit. Branches are thin and flexible. The growing habit resembles that of C. arabica. Leaves are dark green, glossy, narrow, 9 to 12 cm. long, and 3 cm. wide, and they are densely clustered on the branches. Flowers have 8 or even more lobes and occur in small numbers on the nodes. They spread over the whole bearing surface and are often also terminal on the branches, opening the year round. Berries are a brilliant glossy black, small, oblong or round, with variable discus. The skin is thin, the pulp juicy and soft so that the beans can easily be pressed out. Freshly pulped coffee is white like C. arabica. The parchment skin is thin and greyish white. The silverskin has a thickened line on the back of the seed, and accordingly the seed shows a slight groove. The proportion of berries to market product is 6:1 to 7:1.

The "highland coffee from Sierra Leone" in the Cultuurtuin proved to be very resistant although

not immune, to *Hemileia* rust. In May 1897 the tree introduced in 1895 showed a rather serious attack of leaf disease (Stennekes, 1898, p. 619). *C. stenophylla* grows well, in a pyramidal shape, and the stem keeps its branches well to the base. *Corticium* can do a good deal of harm to the trees, but the remaining branches fill the open space. It is very sensitive to root fungus; probably fairly resistant to nematodes, slightly susceptible to berry borer in one test. The yield is moderate. Figures on growth, yields, and variations of the characteristics are recorded by Cramer (1913, p. 606).

COFFEA AFFINIS

A second black berried coffee has been described by E. de Wildeman as *Coffea affinis*. Its berries resemble *C. stenophylla*, its leaf characteristics those of *C. liberica*. Plants were raised in the hothouses of the Jardin Colonial, Nogent sur Marne, from *C. stenophylla* seed received from an estate in French Guinea which had been planted heavily with *C. stenophylla*. Plants were quite different from *C. stenophylla*, and afterwards similar plants were found in gardens in Guinea (Anon., 1904-5a, p. 517). De Wildeman described the species on the basis of incomplete material (p. 114). Chevalier (1905a, p. 1474) mentioned it from French Guinea, adding that it was not spontaneous there, but found only in plantings in Conakry. In 1908 it was stated again that in 1900 among seedlings of *C. stenophylla* a few plants were found with the vigor and the leaves of *C. liberica* but with the branching habit and small black berries of *C. stenophylla* (Henry, 1908, p. 203). From the description of the appearance of the new form, which is quite similar to the appearance of hybrids of *C. stenophylla* when the seed of the clones in the Cultuurtuin near the libericoid species are planted in the nursery, it seems beyond doubt that *C. affinis* is simply *C. stenophylla* x *C. liberica*. Chevalier (1929, p. 121) described the plant which had furnished the samples on which *Coffea affinis* De Wild was based, as a hybrid born in the Experimental Garden at Camayenne. The form introduced under this name into Java confirmed this. The plants were weak (van Hall & van Helten, 1917, p. 17) and have since disappeared.

Chevalier's *C. togoensis* is apparently a species closely allied to *C. stenophylla*, but it has narrow oblong berries (Chevalier, 1939, p. 402). Moore (1911-1912, p. 95) mentioned it as a new species from Gazaland, east Africa, to be inserted next to *C. stenophylla*, which had been described as *Coffea swynnertonii* S. Moore. The new species differs from *C. stenophylla* chiefly by its much smaller leaves, berries, and seed. It is found at 400 feet in the Madanda forests and under cultivation near Chirinda at 3,000 feet. The "Inyambane coffee" of settlers may be a form with somewhat larger leaves. This coffee grows wild in quantities on the Yuabota River, Portuguese East Africa, at about 1,000 feet. The product is said to be of excellent quality (Moore, 1911-12, p. 95). With this species another small leaved one of the same country was described as *Coffea ligustroides* S. Moore. The fruit is yellow when ripe, oblong, and one-seeded and the flowers are four-lobed. It was found at 3,800 feet in the Chipete Forest Patch. It yielded the Chirinda coffee (Moore, p. 94). Both kinds were cited by Chevalier (1929, p. 96).

COFFEA CONGENSIS

C. congensis was first described by Froehner (1897, p. 235), who stated that it resembled *C. arabica* but different from it by the narrower, thicker leaves and larger calyculus. It occurred wild in the Belgian Congo and in French Equatorial Africa along the Ubangui, from Liranda to the confluence with the Kwango (Chevalier, 1903a, p. 258) at an altitude of 350-450 m. Further literature on the places where it was found wild is cited by Cramer (1909, p. 73). De Wildeman reported that Laurent found *C. congensis* opposite Coquilhatville in 1896 (de Wildeman, 1903, p. 35). The "cafétier du Lualaba" found by Laurent on an island of this river near Walundu and opposite Coquilhatville on the Congo was noted by Leplae as only a little different from *C. arabica*. Apparently in this case the wild trees belonged to *C. congensis* as already recorded by de Wildeman. The fruit was described as small and oblong (Leplae, 1936, p. 14). It was described at first as absolutely resistant to *Hemileia*, and it does indeed show a strong resistance although it is not wholly immune (Fauchère, apud Cramer, 1909, p. 78). A single case was reported in the Cultuurtuin (van Hall & van Helten, 1917, p. 10, note), but since it related to seedlings and since the species hybridizes very easily, it was not certain that the infected tree was pure *C. congensis*. *C. congensis* was also observed subsequently as not being absolutely free from *Hemileia* (Cramer, 1918-19, p. 120).

Of all the species of *Coffea* it is obvious that this is the one which resembles *C. arabica* most closely. It grows into a densely branched shrub. The branches are thin, but not so flexible and bent as in *C. arabica*. The leaves are narrow, bright green, 12 to 20 cm. long and 4 to 6 wide. In branching habit it also resembles *C. stenophylla*. The number of flowers per node is small. The corolla has 6 to 7 lobes. The berries are small and have longer stalks than *C. robusta*. The skin is thin and juicy and the ripe berries are even blood red. The freshly pulped coffee is white, like

C. arabica. The parchment skin is thin. The silverskin loosens easily from the bean, another similarity to C. arabica.

Characteristic of C. congensis is the long peduncle about 7 mm., so that the fruit is arranged in loose whorls and not pressed together in thick clusters. This makes the species resemble C. arabica more than C. robusta. There is, however, one variety, C. congensis Froehner var. subsessilis de Wild., of which the peduncles are short (de Wildeman, 1905-1907, p. 337).

The resemblance of C. congensis to C. arabica is frequently mentioned by those who found it in the wild or who studied material from wild trees. Pierre was of the opinion that C. congensis might be a simple variation of C. arabica (de Wildeman, 1905-1907, p. 338). De Wildeman (1908, p. 54) even thought that the so-called C. congensis species might well be a cultivated C. arabica which has reverted to the wild state.

Ledreux' description (1932, p. 126) of C. congensis in Madagascar was close to the characteristics mentioned above, and the crop was seen to ripen in the same season as Robusta. It was introduced to Madagascar from the Jardin Colonial in 1901. Apparently these seed reproduced the pure species.

The market product has been described frequently as having a good taste. The French coffee expert H. Vermond found the taste "peculiar, but far from unpleasant" (Cramer, 1909, p. 79). According to a missionary in Africa, Le Tisserant (1929, p. 27), the product was known there as "café des îles" and considered of superior quality. A sample submitted to the well known Java planter T. Ottolander was judged by him as better than low country Robusta, but less flavorful than arabian from his own estate. His estate was located in a region which produces perhaps the best tasting coffee of all Java by virtue of its high altitude (Cramer, 1924, p. 42).

Like most species of coffee studied in this connection, C. congensis appeared highly variable in the wild state. When plots were planted with seed from wild trees, they resulted in trees showing great differences in the part of the tree, the disposition of the branches, the size and shape of the leaves, of the flowers, and of the fruit. None of the numerous different types suggested that it resulted from hybridization with some other type of wild coffee, such as for instance, C. canephora (Miny, 1927, p. 155).

The general characteristics of C. congensis are such that Chevalier (1926, p. 668), when trying to group the some 60 species of Coffea described up to now, placed it in the same class with the species C. arabica and C. mauritiana. C. congensis was first introduced into Java in 1903 and thereafter on several other occasions. Data may be found in Cramer (1913, p. 694).

The difficulty with Congensis in Indonesia was that it apparently had a weak root system, and did not grow well in the Cultuurtuin. The only way to keep the plants there was to grow them as grafts, and even then they never flourished. Grafts made at Bangelan developed better and gave fair yields. In 1912 the seed was used to lay out a field which, compared to a field of Arabica in the same corner of the estate, was quite productive. If the years 1918 and 1919, with a crop failure due to an outbreak of berry borer and the eruption of the Kelood volcano, are excluded, the yield from 1916 to 1923 was 332 kg. per hectare, with an average of 459 kg. for six years. This is only about half of what Robusta would have given, but much higher than the yield of Arabica under those conditions.

The experimental planting revealed another desirable characteristic of C. congensis, that was at least locally, the early ripening of the crop. Whereas the Robusta crop of February-April was only about 2 per cent of the total annual crop it was over 17 per cent for C. congensis; and in May this coffee gave 23.4 per cent against 13.5 per cent for C. robusta (Cramer, 1924, p. 43). Some time before, I had recommended trial of C. congensis in places where C. arabica was already doing well (Cramer, 1916a, p. 402) and suggested, preferably the use of grafts, since small plantings of grafts from superior C. congensis trees gave quite good yields. However, no such experiment was ever made. C. congensis coffee has never attained commercial importance. Some of its hybrids, however, the so-called "Congusta" or "Conuga", which inherits several characteristics of both Congensis and Robusta mother trees, became more widely used, especially in the higher altitudes.

In the wild various divergent forms of C. congensis are found. As such we may cite the C. congensis var. froehneri Pierre. According to Dewèvre it showed pink flowers. The fruit, when ripening, at first became a carmine brown and ultimately a black brown (see de Wildeman, 1901, p. 16). As already stated, a variety with short peduncles, in contrast with forms like the C. congensis varieties subanghiensis, froehneri, and chalogii, is recorded by de Wildeman (1905-1907, p. 335, 337). An interesting form was one he described (1901, p. 17) as C. congensis Froehner var. chalogii Pierre nss., occurring in Gabon and in the Congo. That writer cited several habitats in the Belgian Congo for the var. chalogii. In the latter country it was found by Dewèvre on the banks of an island between Lukolela and N'Gombi, apparently the same place where C. congensis var. froehneri Pierre was found by the same explorer. In contrast with this observation that variety froehneri only occurred

at the edge of the forest near the river and not in the interior of the island (de Wildemann, loc. cit., p. 16), the variety chalotii was also found at a certain distance from the river. This latter variety might be a spontaneous hybrid of C. congensis with some wild robustoid form widespread in the Congo forest. However, this form was introduced into Java from the Agricultural Service in Madagascar (Jaarboek, 1908, p. 86). The introduced material may have been hybridized, but, this did not mean that the original plants in the jungle were hybrids. Quite possibly the crossing took place in a botanical garden.

Hille Ris Lambers reports having seen two very different types of C. congensis in the Belgian Congo, one of which showed a strong resemblance to certain forms of C. eugenioides.

Mother trees of C. eugenioides were also found. Their berries, the shape of the tree, and of the leaves, showed a strong resemblance to C. congensis (Hille Ris Lambers, 1939a, p. 1807). Chevalier (1929, p. 90) cited from Sir Harry Johnson that George Grenfell discovered C. congensis in February or March 1884 along the river banks of the lower Ubangui and the lower Sangha. He also mentioned various allied forms, among which were some with smaller leaves and berries.

Coffea brevipes Hiern has many affinities with C. congensis and C. arabica. It was discovered in 1862 by C. Mann in the Cameroun mountains at 650-1,000 m. and was described by Hiern (1876, p. 172). Fleury found it again in the Cameroun in the dense forest near the railroad to Duala near Km. 37 at a low altitude (Chevalier, 1929, p. 92). This species had been introduced into Indonesia by Hille Ris Lambers, who found it in the Belgian Congo. C. brevipes was found in the Cameroun from 1,500 m. on up, but mainly between 2,000 and 3,000 m. It is also mentioned as occurring in virgin forest at 300-1,000 m. it is a shrub, 1 to 4 m. in height, with berries resembling those of C. arabica and equally as large. Froehner (1898, p. 260) distinguished a divergent form, he named as C. brevipes var. longifolia. From all these notes taken from the literature, it will be clear that C. congensis approaches C. arabica on the one hand, while on the other hand it is a species with many divergent forms, some of which tend in the direction of other species. Still, other "good" species such as C. brevipes and C. eugenioides come near to it. There is a possibility that C. congensis var. chalotii is a natural hybrid, but the hybrid form, introduced into Java, may be a hybrid of C. congensis var. chalotii and C. canephora, which had its origin under cultivation in Madagascar.

COFFEA EUGENIOIDES

This species was introduced by the Malang Institute in 1938 after Hille Ris Lambers' trip to Africa. It was found to occur wild in the Uganda Protectorate and in Kenya Colony (see Bullock, 1930, p. 401), and also in the Upper Ituri of the Belgian Congo. It was called the "Nandi Coffee". The Nandi coffee has been cultivated on the government plantation, Kampala, and the government farm at Naibori. At Naibori it was found to be infected with the Hemileia rust.

According to Chevalier (1939, p. 397) C. arabica var. intermedia was not C. arabica, but was identical with C. eugenioides Moore. It is here suggested that from now on, this last species be called C. intermedia (Froehner) Chev. = C. eugenioides Moore.

In the Belgian Congo small experimental plantings of "Nandi coffee" were made at the I.N.E.A.C. station at Nika and at a neighboring private estate. In its native habitat it was a shade loving plant, and found on the banks of most rivers in the interior of Kenya and Uganda, in dense shade at altitudes varying from 4,000 to 6,000 ft. above sea level. Here it assumed a very straggling habit, and attained height of 20 ft. Under cultivation, however, it became a low, compact shrub, almost conical in shape. Both the leaves and the coral red fruit, were much smaller. It is unlikely that "Nandi coffee" will prove commercially valuable. Apart from the small size of the beans, the taste is inferior, and the plant is very susceptible to the rust. (Bullock, loc. cit.).

Apparently the "Kenya coffee" mentioned by Reelofeen (1939c, p. 151-281) is C. eugenioides. He reported that the beans were very small, rather blue, and the taste better than that of "Kapakata" but inferior to that of its hybrid with "Canephora".

The plants grown in the Belgian Congo from seed taken from wild C. eugenioides trees showed considerable variation. That species was grown in the experimental garden of the Malang Institute. Plants of it, put out in the Cultuurtuin, did not tolerate the wet climate of the low country and grew very poorly or died.

Hille Ris Lambers (1939a, p. 1807) paid a good deal of attention to the C. eugenioides species during his visit to Africa, and he was able to trace it even in regions where it had not been previously found. He was able to collect 4 or 5 distinct types in a comparatively small area. Sometimes plants resembling a miniature C. arabica were found. He also found some trees which resembled true C. congensis, strongly with respect to the shape of the berry, leaf, and tree. As a preliminary hypothesis he suggested that there was a connection between the species C. eugenioides and C. arabica in the east and between the same species C. eugenioides, and that of C. congensis, in the west. This did not mean that both C. arabica and C. congensis originated from C. eugenioides but only that all

three may have come from one original type. Apparently as in Vavilov's theory (Vavilov, 1922, and 1926, p. 243): "These mountain regions which border on the deserts of central Asia, or on the Sahara in Africa, represent, by their diversity of climate and soils, optimum conditions for the process of the originating of forms. As to the amount of rainfall, the difference of temperature and the soil types, they are represented in all gradations up to the extreme variants. The diversity of conditions, ranging from desert to oasis, and from soils devoid of humus to soils of the alpine and sub-alpine zones rich in this substance, have favored the origin and the concentration in these countries of an exceptional diversity of vegetation". I have held since 1910 (Cramer, 1910a, p. 465) that these districts are nurseries of species and varieties, and require a special and detailed study as respects the coffees.

It is not impossible that hybridisation also played a role in this richness of types. According to Frahm-Leliveld (1938a, p. 25) there were members of the Robusta group considered as hybrids and also other "species", e.g., *C. liberica*, *C. excelsa*, and *C. dybowskii* that were undoubtedly more or less hybrids. It may be added that this hybridisation might occur, not only in the botanical gardens, where these species have been grown and from which Indonesia obtained its seed, but also in the wild state, since more than one species was found next to another in several cases in the same habitat in the African jungle.

KAPAKATA COFFEE

The introduction of "Kapakata coffee" from Angola has already been mentioned. The species was soon to be grown in various places in Indonesia, such as the experimental garden of the Malang Institute, the Bangelan Station, and the Cultuurtuin, where it is developed well. Hille Ris Lambers (1935a, p. 107) described the small tree as densely branched. The berries were ribbed, and the calyx remained attached to them. "Kapakata coffee" was found to be attacked by scale insects and mealy bug. Only a few berries were attacked by berry borer. No branch borer was found, and dieback of branches was rare in this species. Chevalier (1939, p. 403) determined that Kapakata belongs to another new genus, which he called *Pailanthopsis*.

The commercial value of Kapakata was not fully studied. The trees grew well and produced fairly well, but the beans were very small and the market value undecided (Hille Ris Lambers, 1935a, p. 111). In a later publication Roelofsen (1939c, p. 272) gave a very unfavorable opinion of the product. The beans were very small, very yellow, not free from silverskin, and the taste horrible. In the description by Hille Ris Lambers (1935a, p. 105) of the introduced trees one tree was mentioned as suffering severely from leaf disease. It might be that the species could give valuable hybrids. Hille Ris Lambers (1935a, p. 112, 1937a, p. 990) succeeded in fecundation its flowers with pollen of Robusta BP.42, hoping to combine the large berries BP.42 with the strong, regular branching habit of Kapakata. Kapakata x Ugandae Bgn.la was also made. In 1941 further particulars of these hybrids were given and illustrated (Hille Ris Lambers, 1941, p. 1531). They will be discussed here further on in the paragraphs on hybrids.

"BOTANICAL" SPECIES

There are several "botanical" species which look so different from the better known kinds of coffee that they are hardly recognisable as belonging to the genus *Coffea*. However, their relationship with the other species is revealed by the fact that they have been grafted in Indonesia on species such as *Excelsa*, *Robusta*, etc. In the Cultuurtuin a species was grown under the name of *Coffea sanguinaria* Lour. However, its characteristics did not correspond exactly with those of this species as described by Chevalier. The genuine species was considered as indigenous on the island of Zanzibar and on the coast of Mozambique, where it was discovered by Loureiro about 1757. It is a shrub with chartaceous leaves. The berry is oblong, 12 to 15 mm. in length. The seed resembles that of *Arabica* in shape and size (Chevalier, 1929, p. 97). The kind cultivated in the Cultuurtuin had leathery leaves and did not flower there. Some trees at Bangelan flowered with pink flowers, but fruit and seed were not obtained.

C. gallieni Dubard, is the correct name for a species formerly called *C. perrieri* Drake, ex Jumelle et Perrier (see Chevalier, 1938, p. 831). It was described by Chevalier (1929, p. 103) as abundant in west Madagascar. It is a curious type with small flowers and a pear-shaped berry, greenish-brown when ripe, and 12 to 15 mm. long. After roasting the seeds seemed to have a very bitter taste (Chevalier, loc. cit.). It was introduced into Java, and grafts in the Cultuurtuin in Bogor bore regularly in the past but this was not the case in later years.

Special mention must be made of a kind introduced into Java under the name *Coffea schumanniana* W. Busse. The real coffee species of this name, discovered by Walter Busse toward 1900 near the Mngangala River in the lower Rovuma region of Tanganyika, former German East Africa, has oval, paper-like, thin leaves, with undulating edges and fruit 10 to 11 mm. long and 5 to 6 mm. broad. Frequent-

ly it had one seed per berry. A description with good illustrations was published by Busse in 1902 (p. 142). However the kind introduced into Java did not correspond with this description. The leaves of the trees growing in Java were leathery and the fruit short. According to Chevalier (1929, p. 98), it was not a true *Coffea* but it belonged more properly to another genus, *Psychotria*, that of the family Rubiaceae. It may be noted, however, that it could be grafted with other kinds of *Coffea*. The false *C. schumanniana* at Bangelan fruited well but the extract of the roasted beans had no flavor.

Coffea mauritiana Lamarck, called "Café Marron" or "Café batard" of Réunion and Mauritius is a tree that sometimes attains 20 to 25 m. in height. The leaves are somewhat leathery, 9 to 24 cm. long, with almost sessile fruit. The flower has no odor. The fruit is 12 to 15 mm. long when dried. It is green at first and becomes white as it matures. The seed is smaller than that of Arabica and pointed at one end. It is stronger and less agreeable in flavor than that coffee. Many historical details on this species were given by Chevalier (1929, p. 99). It was introduced into Java from Mauritius and planted at Bangelan where a well developed tree existed about 1927. Subsequently however, it was lost.

C. humilis is a dwarf species found on the Ivory Coast. It was described by Chevalier in 1907 (p. 348 with botanical diagnosis and again in 1908a, p. 79 and 81) as always containing two seeds per berry, even in the small berries. According to a report by Greshof, cited by Chevalier (1908a, p. 81), the beans contained 1.53 per cent caffeine. The color, the taste, and shape of the beans all were those of a good coffee. After roasting the taste was found to be very sweet, pure, and aromatic, not in the least bitter or sharp. This species was introduced into Java in 1908. Two plants were received in a Wardian case from the Jardin at Nogent sur Marne and planted in the Economic Garden at Buitenzorg, where they thrived (Jaarboek, 1908, p. 86). Cramer (1909, p. 6) noted that they showed 5 to 7 pairs of leaves which were placed not in an exact desussate position, but somewhat in a spiral, so that they formed a whorl. Later on the species disappeared from the collections.

CHAPTER 24
THE DIVERSITY OF FORMS

THE CONCEPTION OF "SPECIES" IN COFFEES

It is clear from the preceding chapters that the genus *Coffea* is comparatively rich in species and that a further increase is to be anticipated. At the end of the last century the total number was put at about 25 species (Engler-Prantl, 1897, p. 104), and a year later it was put at 29 (Froehner, 1898, p. 251). When at the end of the last century and the beginning of this the interior of Africa became more accessible, the exploration of west Africa, especially of the Belgian Congo, resulted in the discovery of many new forms which de Wildeman (1901) described and named. He soon published (1908, p. 140) with further additions 2 years later (1910, p. 359). The commercial importance for tropical agriculture which the newly discovered soon acquired stimulated further searches.

In later years Chevalier (1929) reviewed the genus again. Chevalier intensified his studies including his field work, and the *Journal de Botanique Appliquée* contains many valuable contributions on new forms of coffee. In one of his later publications is a review of the species indigenous to Madagascar and neighboring islands, and the nearby part of the African continent. From this area, Chevalier (1938, p. 826) described not less than 23 *Coffeas*. Froehner has enumerated only 3 species for southeast Africa in 1898 and 3 from the nearby islands, and thus in 40 years time the number for this area was nearly quadrupled. This shows the great progress that has been realized.

The number of species of coffee is generally put at a figure between 40 and 60 or 70. In reality more species than that have been described. In recent years a list has been published of the names and synonyms of all those described (Houk, 1939) with references. It is a carefully compiled, very useful work which every worker on coffee will appreciate, for the nomenclature of coffee is rather confused. Houk enumerates well over 100 species, but not all are what might be called "good" ones. Some are hybrids with origins in botanical gardens, some are incompletely described and possibly identical with others under a different name. On the other hand, some undoubtedly good species are not mentioned in Houk's list, probably because the literature in which they were described was not at his disposal. As such we may mention the Arabica-like species from Kivu, *Coffea kivuensis* Lebrun, and *C. van roechnoutii* Lebrun. Many species have been described after Houk's list came out, for instance, those in Chevalier's publications of 1939 must still be added to the number already enumerated by Houk so that the total of undoubtedly "good" species is probably over a hundred.

The whole question of the number of species is rather arbitrary. The difference between some are so small that many botanists would prefer to bring them together into one "good" species. Among the seedlings of one population such great differences many occur that if extreme types were chosen they might be considered as belonging to different species. On the other hand, the consolidation of well defined forms into one species may sometimes go too far. In the old days when Arabica was still the dominant kind there was a tendency to include quite distant species in this linean species, and even a "good" species like *Congensis* was once thought possibly to be Arabica that had reverted to the wild (de Wildeman, 1908, p. 54). It is the old argument between the "splitters" and the "lumpers" among systematists, a circumstance not infrequently due to an enforced concentration on morphological aspects (Diver, 1940, p. 305).

The difficulties arise from the fact that all or most species of *Coffea* are in a state of variation and mutation and include in their centers of origin a large number of divergent forms. No systematic studies on this point have yet been made, but all the evidence suggests that among the wild plants of the known species, many varying types occur. The more the plants of economic importance are studied, the more this is found to be the rule. A century ago van Mons explored the Ardennes in search of wild forms of apples and pears. He raised seedlings from them with great care and in another climate, thus improving their fruit. Van Mons considered them as subspecies and recognized fully that "only nature creates". Hugo de Vries (1901, p. 126); referring to van Mons, at the beginning of this century, again directed attention toward this source of progress for agriculture. It is well recognized that many tropical crops are of comparatively recent introduction. The original wild forms are still in existence, as in *Coffea*, *Hevea*, *Ficus*, *Piper nigrum*, *Manihot*, and *Cactilia*. These kinds in the wild state show many "small" species, that it has long been known should be introduced from the wild into tropical agriculture.

In such a crop as coffee the best hope is in keeping the forms separate as they are being studied, but forming a dynamic and moving, malleable mass, from which the best may be selected for agriculture.

GROUPS OF ALLIED SPECIES

This dynamic conception of "species" seems to apply very well the *Coffeas* in Africa. First

the special group of C. arabica and allied species may be discussed. Little is known about C. arabica in Abyssinia, but what is known supports the idea that it is a group of multiple forms instead of a uniform species such as is known in commercial plantings. Seed from Abyssinia which came from trees under cultivation there, but only a few generations removed from the wild trees, were planted in Java and produced a kind differing from the Java Arabica and showing a much higher resistance to leaf disease. It could be planted with success at a lower altitude where Java Arabica would have failed. The recognized variable forms of C. arabica which are known in central and east Africa are an added indication in the same direction.

The occurrence of the very variable species, C. eugenioides, in the higher altitudes of central Africa, and the Kivu mountains, demonstrates further the spreading of the forms allied to C. arabica. The C. congensis species is another form closely related to the C. arabica species. However, its habitat is the low country. It occurs along the Congo River, while Arabica is confined to higher mountains. Congensis is, by itself, again represented by several forms. In view of the large area over which it is distributed, there is a fair chance that further divergent forms will be found. It is a curious fact that this coffee, native to temporarily flooded river banks, was well known to have a weak root system in Java, and could not hold up in a soil such as that of the Cultuurtuin.

As a last allied form C. stenophylla must be mentioned. It is marked in having black fruit. Certain Asiatic species show this same characteristics. It is most closely related to C. congensis, but it is far less widespread. It is a strange fact that while true C. stenophylla is only known for west Africa, as in Sierra Leone in particular, closely allied species are found in east Africa.

Next, mention should be made of C. liberica and allied species that form a second group. A distinction must be noted between the group C. liberica in a strict sense and the exceloid group. The typical C. liberica bears hard, thick-skinned fruit, generally oblong in shape and yellowish-red in color. The red appears in fine, short stripes. The typical C. excelsa is characterized by short, broad, juicy berries of an even dark red color and shiny in contrast with the dull Liberica fruit. With C. liberica the somewhat fleshy, large flower shows 6 to 8 petal lobes; while in C. excelsa the flowers are smaller, of thinner texture, and usually 5 lobed. Both species grow into tall, vigorous trees with broad, large, leathery leaves, but the berry characteristics are so distinct that it does not seem rational to unite C. liberica and C. excelsa into one large species.

C. liberica, in itself an extremely variable species, is closely allied to several forms indigenous to west Africa, all with smaller fruit. The original habitat of C. liberica is not known with certainty, but it is highly probable that the species comes from the Liberian hinterland. In this region trees of C. abeokutae also occur wild. In these, the berries are clearly striped with carmine and yellow, are shiny, oblong, juicier, and with a thinner skin than C. liberica. Soon after C. liberica became known there was a report from Liberia of a distinct variety, bearing 18 months earlier, and having a smaller berry. However, the larger variety was preferred as yielding a superior coffee and a larger crop (Questions, 1876, p. 2).

Both C. arnoldiana and C. dewevrei are similar to C. abeokutae but they have rounder berries with a thicker skin. The C. aruwiniensis bears dark red fruit on which the color is distributed as it is on C. liberica berries. All these forms occur over the forest regions of the Congo basin and over the gallery forests in the drier regions. C. excelsa has as its close allies C. dybowskii and C. klainii, the latter perhaps identical with C. dybowskii. They are reported in Gabon and the Ubangi. A few years ago Chevalier described a small-leaved form from the Mayumbe, the variety Gogweileri, and another narrow leaved form, C. oeyemensis, connecting C. abeokutae and C. klainii. Other forms mentioned in literature also apparently belong to this group, for instance, C. macrochlamys from Togo.

A third group of species, now united under the name Robusta, furnishes a further example. C. robusta, probably identical with C. canephora var. sanjuruenis and C. laurentii, presents many variations. Several wild varieties of C. canephora have been described. Quillou, a stable form out of the same group, occurs wild in the low country of French Gabon. Another group of robustoids, including C. ugandae, C. bukobensis, and similar forms, is found in the central African mountains. To this group also belongs the important form introduced from Uganda into Java, which received the number SA.425. Some morphological work we did in Java may be mentioned in this connection. The various characteristics by which Robusta clones can be identified have been described in detail by Hille Ris Lambers (1938, p. 165). His minutely detailed descriptions are not only useful for determining to which clone a graft belongs, but also might be used as a manual for describing wild trees of a new species of coffee, especially since his descriptions would help to bring out individual differences and contribute to a better understanding of the polymorphy so common in the species of this genus. The descriptions take into account the variability of each characteristic studied.

There are still a number of other species not included in the four groups mentioned. For

instance, *C. humilis* and the Kapakata coffee, which are distributed in various smaller areas of Africa, and the southeastern African and the Asiatic forms also can be mentioned. No data are available on their variations and alliances in the wild state.

SPONTANEOUS HYBRIDS

The various "good species" mentioned above are so widely distributed through the lower regions of Africa that very often species of two different groups occur in the same locality. Members of the large leaved liberoid group can sometimes be found in the same forest. Hille Ris Lambers found in the Kurukwatta forest, the species *C. eugenioides*, represented by a curious form with leaves resembling those of Arabica but with reddish young leaves at the tops of the branches. In the same forest he found a narrow-leaved robustoid form which resembled to some extent a kind raised from a few dry seed found in an herbarium sample of coffee obtained from the Lotti forest in the Sudan. The occurrence of *C. congensis* and a robustoid species in the same locality has been recorded. Opportunities for spontaneous hybridization in the wild are not lacking.

However, so far no spontaneous hybrids of coffee have been described as found in the wild. But it must not be forgotten that the whole study of the wild *Coffea* is in a rather primitive stage and not comparable with the research which has been done on the wild plants of Europe and their spontaneous hybrids. That such hybrids may be expected with coffee can be seen from a few figures from Switzerland. For that country 2,634 species of higher plants have been described which belong to genera with more than one species there, a condition that makes hybrids theoretically possible. There were 974 spontaneous kinds of hybrids that had been recorded, or about 41 per cent. There are in Switzerland 328 genera with two to fifteen species, and hybrids are found in 101 or 30 per cent of these. There are 34 genera that contain more than 15 species, and for 24 of these genera with numerous species, 70 per cent have produced hybrids. This shows how frequently spontaneous hybridization occurs in the wild, when the essential condition of a large number of species is fulfilled (Lotsy, 1926, p. 445). On this evidence a rather frequent occurrence of coffee hybrids may be anticipated in localities where two or more species of coffee grew intermingled.

The experience with cultivated coffee leads to the opinion that coffee hybridizes rather easily. The self-incompatibility, frequent with robustoid kinds, can be cited as a factor which may force spontaneous crossing of species. The tendency of the pollen tube developed from foreign pollen to grow faster than the tube developed by the pollen of the same flower is another factor in favor of hybridization. Spontaneous crossings between different, even between distant, species are not very rare.

Hille Ris Lambers (1941, p. 1531) crossed Kapakata coffee with Robusta although the difference between these two species is so great that Chevalier (1939, p. 403) considered them as belonging to different genera. Hille Ris Lambers also obtained a cross between shrubs out of a completely different group. This cross is the more remarkable because *C. hornefieldiana* has $2n = 44$, while the sematic chromosome number for *C. robusta* is $2n = 22$.

In other cases a similar difference in chromosome numbers seems to offer more difficulties. Cramer, in visiting an estate where extensive fields of Arabica ($2n = 44$) had been supplied with Robusta ($2n = 22$) plants, found some of the latter occurring as single plants isolated and separated from other Robusta trees by several rows of Arabica so that intercrossing with a tree of the same species was hardly possible. A planting was set out with seed of such trees and proved to contain 2 hybrids of *C. robusta* x *C. arabica* in a total of 700 trees. Spontaneous crossings between Robusta x Maragogipe have been found on estates, but not frequently. Schweizer succeeded in making the reciprocal cross between the typical species. Hille Ris Lambers and Krug obtained the parallel cross. There have also been several instances of fields of Arabica interplanted with Liberica as supplies, but the number of spontaneous hybrids of the two actually discovered is comparatively small.

The difficulty of intercrossing between the species just mentioned might be attributed to the difference in chromosome numbers, but in cases where they are equal for the potential parents, the same difficulty is encountered. Conditions favorable to intercrossing of robustoid and liberoid species must also have existed, although less frequently than in the foregoing instances. Still crosses between the two species are not often found.

I studied these in Java, in the period 1915-1919, and was able to bring together a small set of spontaneous hybrids of robustoids and liberoids found on estates, and could even select one valuable form from them, the QP hybrid, although the choice was limited. In later years I planted seed from various clones in the Economic Garden in Bogor, where a single row of grafts of one Robusta clone was sometimes bordered on both sides by several rows of liberoid clones or clones belonging to entirely different species. The appearance of hybrids was very rare. Robusta Bgn.372, for instance, which is considered self-incompatible, produced plants which showed only pure Robusta char-

acteristics up to the age of about one year, even though practically all these clones flowered simultaneously, and frequently, in the moist climate of Buitenzorg.

There are a few species that seem to have a tendency for crossing. Perhaps the most striking instance is C. stenophylla, which, when it is exposed to pollination by a liberoid kind, will practically always produce a fair number of hybrids (Cramer, 1913, p. 610). In the work done, they were easily recognized, even as young plants in the nursery, by their much broader leaves, contrasting with the narrow Stenophylla leaves, and when somewhat older, by the more vigorous growth and reddish young leaves at the top of the stem. C. congensis was found to combine easily with robustoids that were then called "congusta". These plants, found as spontaneous hybrids in the progeny of each of the parents, showed this fact clearly. In both cases the parents could not be called closely allied species.

When it comes to combining species belonging to the same group, hybrids can generally be obtained very easily by hand crossing. In a clone collection they often originate so frequently that the problem is less how to obtain such hybrids than how to prevent the mixing of the various small species of the same group spontaneous intercrossing. When the first C. excelsa trees raised from introduced seed started to fruit in one of the experimental plots in Buitenzorg, the first four ripe seed produced four hybrids with C. liberica. When the seed of a seedling planting of C. abeokutae in the Economic Garden was distributed to estates, a large percentage produced hybrids, since the mother trees had been exposed to pollination by nearby C. liberica. The plantings of C. canephora and C. ugandae on estates were frequently not composed of pure progeny of these subspecies for similar reasons. They were mainly hybrids. When the first seedlings of C. robusta and C. quillou were planted near one another, a hybrid of C. robusta with C. quillou was found, that became the clone Bgn.124.

From the foregoing it may be concluded that, in the wild state, coffee species, even distant ones, can be hybridized. In the cultivated state, hybridization takes place so easily that when different coffee species are grown together, this possibility must always be reckoned and Boonstra's (1934, p. 1) calculations give an idea of the enormous number of combinations possible even with a restricted number of genotypic differences, say 5, 10, or 15.

INTRODUCTION FROM THE WILD

From the newer conceptions of wild coffee species, some conclusions may be drawn as to the proper way of introducing new forms from the wild into agriculture. All that is known about the wild forms of coffee in the African jungle leads to the belief that there must certainly exist there a wealth of forms which has hardly been touched. What is required for the various coffee growing countries is a thorough study of all this extremely valuable material in order that full advantage can be taken of it for the improvement of the planting industry everywhere.

Relative to this the present writer insisted on the value of the wild forms ever since his first work in Java in 1905. It was found that the wild trees showed great variability, and it was requested that explorers should pay attention to this point when seed was collected for testing the newly discovered forms under cultivation. As we stated elsewhere. "The science of variability should penetrate along with its older sister, systematics, into the unexplored jungle of tropical Africa. Even in the wild state the species show this great variability". It seemed of most importance that "when an explorer discovers a new species, he should direct his attention toward the many variations which he may find. He should collect the seed of each separately in order that separate progeny of each tree may be raised". The collecting of the seed should be done "in the country of origin by the advanced posts of the peaceful army of agriculturists". The further work should be entrusted to headquarters in the country for which the material is of interest, where the testing would have to be done under various conditions (Cramer, 1910a, p. 461). A special garden for this kind of work was started in 1916 (Cramer, 1914, p. 653), but in 1924 it was sacrificed to financial retrenchment (Jaarboek, 1924, p. 24).

The principle was probably applied to wild plants for the first time when I collected (see Cramer, 1914a, p. 13) seed from wild Hevea trees in the Amazon valley. When planted in the Economic Garden in Buitenzorg, the individual progeny at once revealed marked differences in growth (p. 13). In later years I again did the same for rubber and I also collected seed separately from mother trees of C. arabica on an estate in Abyssinia, and they were successfully introduced into Java (Gandrup & Schweizer, 1931, p. 52, and Schweizer, 1933a, p. 69). When Hille Ris Lambers (1939a, p. 1806) made his trip to Africa in 1938 he applied the principle of keeping the seed of each wild tree apart, also paying attention to the variations. As a result, the experimental garden in Malang had several individual progenies of highly interesting wild species, especially of C. eugenoides, which he had found wild in various places in central Africa, in Kenya, Uganda, Kivu, and the Belgian Congo. Vavilov (1926, p. 141) developed systematic methods for this kind of work and made the following statement. "A concrete and exact establishment of the geographical centers indeed opens before the

plant breeder wide possibilities of a practical character insofar as it enables him to find the sources of varietal wealth". The remarkable early work done by the scientists of the old Institute in Leningrad, studying the wild forms of the potato in South and Central America; studying the wild forms of several important grains used for human food such as wheat, rye, and barley; studying the wild fruit trees; and the study of other useful plants, long ago showed the value of the wild material for crop improvement (Hudson, 1937, p. 285). A comparison of the old way of collecting and propagating wild material with the new way, gives a striking contrast. In the old days as was often true with coffees, the explorer took a few handfuls of seed at random from the wild trees and gave them to a botanical garden. There the young plants were often set out next to other coffee plots. This was a disadvantage as is apparent. In the first place, there was no certainty that the full wealth of forms of the wild species was introduced. A rational policy prescribes that the collection of seed should not be restricted to one habitat, but the forms should be traced, if possible, in several places. Everything that can be noted about the variations of wild plants, the occurrence of diseases and pests on them, their natural habitat, and their behavior in the wild state, will be of utmost value to the breeder.

The second disadvantage lies in the danger that the introduced seed may have been hybridized in the garden where they were grown. It is almost certain that some forms of coffee introduced into Java were not the pure species. With wild plants, of course, the possibility of spontaneous hybrids is not excluded, and this is a point of which the seed collector should be aware. However, under certain conditions this difficulty can be avoided by collecting grafting wood rather than seed. This is only possible when there is an experiment station or estates not too far from the habitat of the wild form, where stocks are available, and where grafting can be carried out. This method has an advantage in that the collector is not bound to a limited season for gathering seed. The trees of many species bear ripe seed only part of the year. Another way to overcome this difficulty is to look for spontaneous seedlings which can nearly always be traced near the adult trees. Such plants, carefully dug and packed, can travel a long distance and make it possible to collect material in any season of the year.

THE SEARCH FOR RESISTANT FORMS

In addition to attempting to increase the productivity of the planting material and to improve the quality of its product, scientific breeding strives to intensify the resistance of plants. The term resistance means not only a reduced susceptibility to diseases and pests, but also a general ability to withstand adverse conditions such as poor soil, unfavorable weather, and improper cultivation, to which some forms are more sensitive than others.

In a country like Java the reserve land still available for opening new plantations is getting scarcer, and it is easy to see that the situation will become more acute in the future. The soil is the most important factor in planting. In the old days new plantings were set out on jungle soil from which the heavy forest had been cleared. Thus land with a good cover of humus was ready to receive the young plants. At present new plantings often must be made on land which has been under cultivation with coffee or with some other crop for years. Such fields have lost a large part of their original fertility, even if careful measures have been taken for the prevention of erosion. The exposing of the soil to the tropical sun and showers leads to a reduction of the humus content. Although the use of mulch, cover crops, shade trees, and livestock manure may compensate for this loss to a certain extent, it is common experience that the planting of old land requires more care and gives poorer results than planting on virgin soil.

Since Hemileia vastatrix made its first appearance in Java in 1879, other new diseases and pests have appeared successively. So far, it has been possible to keep them somewhat under control, and it is to be hoped that it will be possible to do so in the future. On the other hand, one must not lose sight of the fact that even if a disease is kept under control, it still takes its toll from the trees. This cannot be calculated, but it represents a heavy tax which nature puts on the estate and often to a greater extent on the native planting. Besides this annual burden there is still the danger that the adverse factor may increase and be aggravated to such a degree that the life of the planting is threatened. Such a view of the future urges continuous attempts to give the planter more resistant forms. There are several paths to this objective.

A thorough exploration of wild forms may lead to the discovery of forms adapted to less favorable conditions. Such forms are likely to be found on the fringes of the area of distribution. In the center of the area, special attention must be given to the occurrence of disease. If a species has been able to maintain itself notwithstanding the presence of a disease, it must have been able to reach a state of equilibrium, or perhaps, better, a state of compromise with its enemy. The difficulty lies in the fact that two living organisms, the crop plant and its enemy, are involved. Both are plastic, and if the breeder improves the resistance of the plant by artificial selection,

nature may do the same for the virulence of the disease.

In this connection it may be mentioned that, according to literature, Hemileia-resistant forms of coffee have been found in Portuguese East Africa, viz., Coffea salvatrix. It does not seem impossible to discover resistant or even immune forms of C. arabica in its original habitat. As Gilbert (1940) remarked, in 1908 a plant explorer's success was measured largely by the wealth and variety of material which reached his countries shores and survived. Today a plant-seeking expedition can be counted a success if a single plant resistant to a particular disease, although otherwise worthless, is brought back for breeding purposes.

In addition to the possibilities of producing Hemileia-resistance in coffee hybrids, practice has shown that several interspecific hybrids are practically immune. The oldest hybrid between C. arabica and C. liberica, the "Kalimas" hybrid, has been under observation since 1885, and it is still as resistant as it was in the beginning. The same can be said of "Kawisari", the reciprocal cross. Chances that the disease should suddenly increase in virulence on these hybrids seem minimal. All experience with interspecific hybrids indicates that they are not only Hemileia-resistant, but also that they show a general resistance against all adverse conditions. They may be considered as a reserve which, if new enemies of coffee appear, may help the industry to survive. It may be expected that in future years more and better hybrids will be produced and that the most promising ones, to which group certainly belong Schweizer's Arabica x Robusta and Arabica x Congusta hybrids, will be better tested. In this direction lies the greatest hope for further developments.

CHAPTER 25
CHROMOSOME STUDIES

HISTORY

For a good number of years, considerable study has been devoted to the cytology of coffee with a view to providing a basis for experiments in hybridization. In Brazil, C. Krug and his collaborators, and in Java, Heyn and Frahm-Leliveld have done meritorious work in this field. They were preceded by some others who made occasional observations on the number of chromosomes in the various species of coffee. A good description of the problem with definitions of terms was provided by Heyn (1936, p. 11). Frahm-Leliveld (1938a, p. 16) explained the importance of cytological investigations for plant breeding and offered Blakeslee's advice: "Know your chromosomes".

The oldest observations on chromosome numbers in coffee were made by von Faber, who studied the floral development with some species of coffee in 1912. Most of his observations and drawings relate to C. liberica, some to C. arabica, and a few to C. laurentii. He found 16 somatic chromosomes (p. 74) and counted 12 to 16 prochromosomes with the division of the pollen mother cells in C. liberica. Heyn, (1938, p. 104) citing von Faber, Homeyer, and Krug, stated that data of the latter differed completely from von Faber's figures.

In 1932 Homeyer (p. 640) published a short preliminary note on chromosome numbers in the Rubiaceae. He found for the ones he examined, a basic figure of $X = 11$ while $2X = 22$ was found for C. arabica and C. semiexserta. A couple of years later Fagerlind, (p. 223) citing from Homeyer, gave his figure of $2n = 44$. This last figure has been later confirmed by Krug and Frahm-Leliveld. Lebrun (1941, p. 91) mentioned $2n = 22$ for C. arabica var. bourbon.

The study of the chromosomes entered into a new phase when Krug (1934) began his studies of this subject at the same time he was making genetic analyses of C. arabica in Brazil. His first publication on the subject dates from 1934 and gives the chromosome number as 44 for the somatic tissue of a whole set of varieties of C. arabica: varieties Nacional, Bourbon, Laurina, Maragogipe, and Amarella. For C. canephora, for C. robusta, C. excelsa, and C. congensis the number was found to be $2n = 22$. Subsequent data by other workers have confirmed these counts. Krug (1934, p. 166) concluded from his own observations and from Schweizer's description of the C. arabica x C. robusta and C. arabica x C. congensis hybrids that these were triploid, having 33 chromosomes.

Krug's anticipation of the triploid character of Schweizer's hybrids was fully confirmed when Frahm-Leliveld studied the cytology of these hybrids. Krug was also able to prove the triploid character by making the cross of C. arabica x C. canephora in both directions. Only one plant was grown, and it had 33 chromosomes. He found that in C. canephora several pairs of chromosomes were longer than the rest. Since the triploid had one haploid chromosome set from that species, the presence of the longer chromosomes was anticipated and, indeed, could be stated. The growth rate of the triploid plant was much less than that of diploids and tetraploids, probably since the initial development of the plant was retarded by the lack of nutritive tissue in the seed (Krug, 1937, p. 411-412). Further data on species of coffee were collected by Heyn, who published in 1936 (p. 11) and 1938 (p. 103) his results obtained from studying the root tips of very young seedlings. Heyn's table no. 1 (loc. cit., p. 105) is reproduced here:

| Type | Chromosome number 2 n |
|------------------------------------|-----------------------|
| <u>C. liberica</u> | 44 |
| <u>C. excelsa</u> | 22 |
| <u>C. abeokutae</u> (Ct.179.01) | 22 |
| <u>C. canephora</u> (Ct.465.102) | 22 |
| <u>C. robusta</u> | 22 |
| <u>C. congensis</u> (no. 6) | 22 |
| Kawisari B | 44 33 (and 38) |
| Kawisari D | 44 |
| <u>C. arabica</u> x <u>robusta</u> | 44 (Besuki Institute) |

Heyn (1936, p. 22 and 1938, p. 105) was the first to include hybrid seedlings in his study. His figures were subsequently confirmed by Frahm-Leliveld, except the one for the species C. liberica, which is the same as for the other liberoid species examined by Heyn, viz., 22. The extreme facility with which Liberica, Excelsa, and Abeokutae all intercross is also an indication of this equality in chromosome numbers. Heyn came to the same conclusion as Krug, that Schweizer's C. arabica x C. robusta hybrids would have 33 chromosomes. Heyn could state that only one descendant of the hybrid C. arabica x C. robusta had 44 chromosomes. However, Heyn's conclusion that the fertility

of C. arabica x C. liberica, and reciprocal hybrids, was due to the fact that both species have 44 chromosomes was not confirmed. An explanation may be that the few fertile hybrids of this combination come out of a fairly large number of similar hybrids found as chance hybrids on estates, and thus they represent the result of a rather sharp selection. Heyn (1936, p. 28) also noted that in a root of a Kawisari seedling, which is C. liberica x C. arabica, he found next to cells with 44 chromosomes one cell with many more, probably 88 chromosomes.

In the same year in which Heyn gave his first results on chromosome counts, Krug (1936, p. 1) published his second cytological study on Coffea. He had examined several more varieties of C. arabica, that is: Angustifolia, Erecta, Goiaba, Mokka, Monosperma, Murta, Polysperma, Purpurascens, and three other new varieties. He found $2n = 44$ in all of them. The chromosomes in all these varieties measured approximately one to two microns. They were identical in shape with those of the other varieties studied beforehand. In the C. arabica variety bullata higher figures ($2n = 66$ and $2n = 88$) were found. For the following species Krug found $2n = 22$: C. abeokutae, C. dybowskii, C. dewevrei, and C. ugandae. Lebrun (1941, p. 9) gave $2n = 22$ for C. arabica var. bourbon and stated that he did not find differences in the chromosome numbers for the various species and varieties he examined: C. arabica, C. congensis, C. canephora, C. liberica, and C. stenophylla.

THE BULLATA AND MONOSPERMA VARIETIES

In later publications Krug (1937, p. 399) discussed further detailed study of the cytology of the Bullata variety. It was either hexaploid or octaploid. Similar cases in other plants where broad, roughened leaves appeared as typical of "rough tetraploids" have been described by Blakeslee & Avery (1937, p. 393, 398), who came to associate the characteristically roughened leaves with spontaneous tetraploids. These thick, roughened leaves apparently were due to the different growth rates of the $2n$ and $4n$ tissues. The plants may be called "mixochimaeras". Müntzing (1935-1936, p. 282-283), who compared data on morphological characteristics of a large number of polyploid forms, found that tetraploids generally had thicker leaves of a darker green color. Krug assumed that the Bullata form of C. arabica usually originated as a consequence of somatic chromosome doubling. In the adult tree the meiotic behavior was abnormal, and normal seed set was scanty in both forms.

Various crosses were made. From the cross, tetraploid x octoploid, 7 hybrids were obtained, and all showed typical characteristics of the female parent and had $2n = 44$ chromosomes. Selfed seeds gave seedlings which, with two exceptions, showed the characteristics of normal C. arabica and possessed $2n = 44$ chromosomes. These facts and chromosome counts at meiosis indicated that the functional gametes of the octoploids had either 22 or 44 chromosomes. Octoploid plants are believed to arise by somatic chromosome doubling, and a few instances of vegetative reversions of octoploids to the tetraploid condition have been observed. This somatic chromosome reduction may be revealed in bud variation. The case of the appearance in coffee of the "bullata" form as a bud sport is in accordance with Jørgensen's theory (Jørgensen, 1928, p. 201) that the majority of the polyploid forms owe origin to "endo-cuplication" in the somatic tissue. This theory was further confirmed by Blakeslee, who studied hundreds of plants which were due to chromosome mutations. The duplication of the chromosomes originates in somatic tissue after the formation of the first cell of the embryo (Blakeslee & Avery, 1937, p. 393). In 64 plants treated for chromosome doubling these men found that in 39, tetraploid tissue had been formed somewhere in the stem.

Krug assumed further that the hexaploids originated in progeny of tetraploids by the fusion of an unreduced male or female gamete, with 44 chromosomes, with a normal reduced sex cell or in the descendants of octoploids. They can also arise in the cross octoploid x tetraploid for example in bullata x typica. The hexaploids showed the bullata characteristics to a less intensive degree. For instance, the leaves were not quite so thick and leathery as in the octoploids. In hexaploids, counts at meiosis and in root tips of their progeny, showed that the functional gametes of these polyploids usually had 33 chromosomes.

Krug's (1937, p. 413) investigations are considered so important and throw so much light on general problems that they are reproduced here at some length. Reference will be made to the triploid interspecific hybrid C. arabica x C. canephora. Among other interspecific hybrids with parents of different chromosome numbers a few plants had the chromosome number of their female parents. If they originated through the parthenogenetic development of the egg cells, perhaps due to a stimulating effect of the pollen from other species, followed by a somatic chromosome doubling, homozygous plants of great importance could be obtained from a genetic standpoint.

A note may be inserted here that in experiments with Arabica a 3 per cent solution of colchicine was applied for 4 days to seed, kept for 30 days in a moist, sterilized soil, resulting in a percentage of plants with $2n = 88$ chromosomes. According to the table in the original bulletin (Mendes, 1939, Quadro I, p. 8), after an immersion of only 2 days in a colchicine solution, no affect was observed. After an immersion of 4 days in a 0.15 per cent solution, there were 1 normal

and 3 abnormal plants. After the same treatment with 0.3 per cent colchicine, 2 normal and 7 abnormal plants were obtained (Mendes, 1939; Rev. Bot. Appl., 1939, p. 382).

It is of interest to compare with the bullata form of *C. arabica* studied by Krug in Brazil, a similar form, the so-called "djamboe type" in Indonesia in a hybrid of two robustoid trees, SA.109 (probably robusta x quillou) x BP.42. The Malang Institute had in its experimental plot a number of hybrids of this type with the typical compact growth, very dark green, very curly leaves, and small round berries. Exact data on the diploid number of chromosomes were not obtained as material from vegetative divisions was not available. Counts had already been made previously in the endosperm, but the very divergent figures from this material, which possessed the 2n chromosomes of the "djamboe" type, but next to it still another set of chromosomes from the unknown pollen parent, did not permit determination of the number of chromosomes of the "djamboe" type itself (Frahm-Leliveld, 1939, p. 11). It possessed one or two extra chromosomes or chromosome fragments (p. 25). In another article by the same author, the numbers of chromosomes counted in the endosperms of this hybrid were given as 43, 54, 48. In one endosperm there were 48, 41, 39, 44, and in another 49, 41 (1938b, Table 2, p. 157).

The spontaneous appearance of Bullata -type plants among Robusta is not uncommon, and in Robusta plantings may be seen trees, called "kooltjes", or "little cabbages", on account of the compact growth of the curled leaved branches. Cramer (1908b, p. 531) described their occurrence in the first generation offspring of introduced Robusta trees which themselves had no Bullata types among them. Attention was given to the fact that this characteristic also occurred in Arabica but had never been seen in Liberica. From this and some similar facts, such as the occurrence of Purpurascens and Angustifolia characteristics in varieties of Arabica but never found in Liberica, induced the conclusion that there was a closer relationship between Robusta and Arabica than between Robusta and Liberica.

This case of homologous variation with Arabica and Robusta, but not with Liberica and Robusta, is all the more interesting since Arabica has double the number of chromosomes that Robusta has, while Liberica has the same number as Robusta. Apparently the similarity in chromosome numbers between Robusta and Liberica does not mean a similarity in genes. "They may be separated by long centuries of independent evolution during which the genetic constitution of each may have become so transformed that the two retain very little in common beyond the chromosome number". This sentence, used by Hudson in his masterly review of genetics and plantbreeding (1937, p. 298), in a general sense seems to apply to this special case.

In contrast with the Bullata form, characterized with its increased numbers of chromosomes, *C. arabica* var. *monosperma* is a type with a reduced number. Such "monosperma" plants found accidentally had been years ago among normal seedlings of typical *C. arabica* in Java (Cramer, 1913, p. 193) and of the Typica variety of *C. arabica* and the Bourbon variety of *C. arabica* in Brazil (Mendes & Bacchi, 1940, p. 4). Cramer (1913, loc. cit., p. 193) once described a tree whose lower branches showed the characteristics of typical Arabica, while the upper part of the stem bore branches with Monosperma Arabica characteristics, probably a vegetative mutation. He also described (p. 195) a tree whose vegetative characteristics were pure Arabica but which bore practically no fruit. The very few berries that were formed resembled those of Monosperma in size and shape, and they contained only one bean.

In Brazil, the abnormality was traced after Franco had found a correlation between the chromosome number and the number of stomata in the leaves of various species of coffee (studies by Mendes and Bacchi, 1940). For variety monosperma, the chromosome number of the latter corresponded approximately to that of species with $2n = 22$. The authors described the microsporogenesis in detail and stated that the well known, nearly complete, sterility of the variety was increased by the generally observed indehiscence of the anthers and frequent malformations of the stigma. Occasionally a few one-seeded fruits were formed. Seeds from open-pollinated flowers gave rise to 44 chromosome plants. One 44 or 45 chromosome hybrid has been obtained by using the polysperma variety ($2n = 44$) as pollen parent. In both cases only 22 chromosome pollen was available, the monosperma trees being surrounded by tetraploid plants. Therefore the authors concluded that egg cells with 22 and perhaps 23 chromosomes were fertile. The monosperma variety is classified as "dihaploid".

In this connection Darlington's comment (1932, p. 17) may be cited, that haploid plants are often as healthy and long-lived as their parents, but are never more than half the size in any of their parts. They are, as a rule, entirely sterile, and neither anthers nor fruit are even proportionately developed, and seed formation is exceptional.

Bacchi (1941, p. 486) submitted the formation of the seed of monosperma to a cytological investigation and found that the irregularities started after the beginning of the first meiotic division in the macrosporocyte. In the course of the further development degeneration occurred. Only one complete embryo sac was found among the 87 ovules he examined.

Krug (1945, p. 248) gave a brief summary of all the cytological work on coffee in Brazil, stating that the basic number was found to be 11. Most of the varieties of Arabica, for Brazil the economically important species, were tetraploids with $2n = 44$. In this species one dihaploid with $2n = 22$ and two polyploids had also been found. The work of A. J. T. Mendes on colchicine treatment was summarized. Detailed studies on chromosome morphology in several species and meiosis in diploids, polyploids, and aneuploids have been made. Krug stated (p. 249) that it was apparent that the Arabica species with $2n = 44$, is an allopolyploid, the Robusta coffee, *C. canephora* species, being one of its ancestors. The existence of the true endosperm was proved through genetical methods by Krug, and through a detailed cytological investigation by Mendes. The genetics of interspecific hybrids were studied in some detail, and several genes have been transferred from one species to another. It was surprising that several dominant Arabica genes continued to show dominance in various interspecific, first generation progenies. Investigations were started by C. H. T. Mendes (Krug, 1945, p. 249) to determine the causes of self-sterility in several species of *Coffea*, and the effect of artificial chromosome duplication on this characteristic.

CHROMOSOMES AND NUMBER OF STOMATA

Very interesting observations were made by Franco (1939), who studied the relation between the number of stomata per unit of leaf surface and the number of chromosomes. He found per square mm. the following average numbers of stomata:

1. liberoids: abeokutae, 254; dewevrei, 234; liberica, 326;
2. " dybowski, 252; excelsa, 216.
3. robustoids: laurentii, 356; canephora, 318; quillou, 388;
4. " bukobensis, 333; ugandae, 302.
5. congensis, 305.
6. triploid hybrids, 239 and 236.
7. arabica varieties (24). The average number varied between 148 (var. maragopipe, flava form) and 185 (semperflorens), with a general mean of 167.
8. bullata: 2 hexaploids showed 104 and 127; 4 octoploids: 136, 132, 130, and only for one plant the expected number 72.

The more closely allied species of *C. liberica* s.l. and of *C. robusta* s.l. have been grouped together (1 and 2, and 3 and 4). These and *C. congensis* all have $2n = 22$ and show a mean figure of 234 (*C. dewevrei*) to 388 (*C. quillou*). Only *C. excelsa*, with 216, is very low, even under the triploids (236-239). *C. arabica*, with $2n = 44$, fluctuated between 148 and 185. The hexaploid bullatas remained under this figure. Of the four octoploids only one plant showed a very low figure (72).

The author calculated the variations of these numbers in detail, with their coefficient of variability, and put the data into graphs. His conclusions were that the number of stomata in *Coffea* decreases as the number of chromosomes increases. The size of the leaves did not affect appreciably the number of stomata per square mm. The area of the stomatal openings appeared to vary with the species and directly with the number of chromosomes.

CHROMOSOME NUMBERS

In 1938 Frahm-Leliveld (1958b, p. 155) published a series of chromosome counts for various species of coffee in Indonesia, in a study on the setting of the fruit. The haploid number was found to be 11 in *C. robusta*, *C. liberica*, *C. excelsa*, *C. abeokutae*, *C. dybowski*, kapakata, QP. hybrid (= *robusta* x *excelsa*), *C. ugandae*, *C. congensis*, and *C. conusta* (= *conuga*), and 22 chromosomes in Kawisari B, Kawisari D, *C. arabica*, arla 1 (*arabica* x *laurentii*), *C. arla 16* and *C. horsfieldiana*. In his Table 1, the various possibilities of chromosome combinations in hybrid endosperms were arranged together for (a) with single sets of chromosomes, and (b) after chromosome doubling. In his Table 2 the numbers of chromosomes counted in the endosperms of some coffee species and the types were enumerated. With respect to this, he remarked that the first endosperm nucleus had been formed by the union of three nuclei, in contrast with the nucleus of the embryo, and that therefore the tissue of the endosperm contained nuclei with a triploid number of chromosomes (loc. cit., p. 138). In a large number of species and varieties the triploid condition of the endosperm could be stated by chromosome counts (p. 163).

In a subsequent article Frahm-Leliveld (1939, p. 1) studied about a dozen Robusta clones from Soember Asin in detail to obtain basic information for future selection experiments. For two clones, SA.24 and SA.75b, root material from the clone itself, obtained from plants grown as cuttings, was examined, for BP.42 root material of legitimate seedlings, and for other clones of uncontrolled crossings (p. 4). Con. SA.36 was also included (loc. cit., p. 16). In all types was found a haploid number of 11 chromosomes, except for two abnormal types, a chimera of SA.109 and a "bullata" type originated in a cross between SA.109 and BP.42. Both of these possessed one or two extra chromo-

somes or chromosome fragments. Abnormalities throughout the meiosis were found to be numerous, doubtless on account of the hybrid nature of Robusta coffee (Frahm-Leliveld, loc. cit., p. 25).

In a few other Coffees Mendes (1938a, p. 8) studied the number of chromosomes. In contrast with Heyn's findings, he discovered in *C. liberica* the number $n = 11$. This figure of Mendes was in accordance with the number found by Frahm-Leliveld as $n = 11$ (1938). It is not clear what the cause of the tetraploid character of Heyn's plant may have been. As to the difference between Mendes' figure and that of Homeyer for the species *C. arabica*, Mendes (1938a, p. 8) showed that there was a great resemblance between the somatic metaphase as pictured by Homeyer and his own findings for *C. excelsa*. Citing the literature he also commented that crossings between *C. arabica* and *C. liberica* seemed to be fairly frequent in Java and India. When one thinks of the large scale on which both species have been interplanted, spontaneous hybrids and especially fertile ones, must be considered as not too frequent.

Mendes (1938) also made a detailed study of the chromosomes in *C. excelsa*. He found the somatic number to be $2n = 22$. He was able to classify the 22 into three groups according to size and to give a minute description of them. Class A contained three pairs of 2-3.3 microns in length; Class C, four pairs of 1-2 microns in length; and Class B, four pairs of 2 microns.

From all the data brought together in the preceding pages a table has been made to show the chromosome numbers of the various species, varieties, and hybrids of coffee. Krug's table (1937, p. 400) served as a basis.

TABLE OF CHROMOSOME NUMBERS IN COFFEA

| Kind of Coffee | Number of Chromosomes | | Author |
|---|-----------------------|----|------------------|
| | 2n | n | |
| abeokutae Cramer | 22 | | Krug, 1936 |
| " " Ct.179.01 | 22 | | Heyn, 1936, 1938 |
| " " | 22 | | Leliveld, 1938 |
| arabica L | 16 | 8 | v. Faber, 1912 |
| " L | 22 | | Homeyer, 1933 |
| " L var. nacional, bourbon, laurina, maragogipe, amarella | 44 | 22 | Krug, 1934 |
| " L | 44 | | Fagerlind, 1934 |
| " var. angustifolia, erecta, goiaba, mokka, monosperma, murta, polysperma, purpurascens and 3 new varieties | 44 | | Krug, 1936 |
| " L var. bullata | 66 & 88 | | Krug, 1937 |
| " L | | 22 | Leliveld, 1938 |
| " var. bourbon | 22 | | Lebrun, 1941 |
| " var. bourbon x canephora | 33 | | Krug, 1937 |
| arabica x liberica Kawisari B | 44 & 88 | | Heyn, 1936, 1938 |
| " " " | | 22 | Leliveld, 1938 |
| " " " D | 44 | | Heyn, 1936, 1938 |
| " " " | | 22 | Leliveld, 1938 |
| arla HRL. (arabica x laurina) 16 | | 22 | Leliveld, 1938 |
| " " " ? | 44 | | Heyn, 1936, 1938 |
| canephora Pierre | 22 | | Krug, 1934 |
| " " Ct.465.102 | 22 | | Heyn, 1936, 1938 |
| " " | 22 | | Lebrun, 1941 |
| congensis Froehner | 22 | 11 | Krug, 1934 |
| " " N° 6 | 22 | | Heyn, 1936, 1938 |
| " " | | 11 | Leliveld, 1938 |
| " " | 22 | | Lebrun, 1941 |
| dewevrei De Wild | 22 | | Krug, 1936 |
| dybowskii Pierre ex De Wild | 22 | | Krug, 1936 |
| " " " | | 11 | Leliveld, 1938 |
| excelsa Chevalier | 22 | | Krug, 1934 |
| " " | 22 | | Heyn, 1936, 1938 |
| " " | | 11 | Leliveld, 1938 |
| " " | 22 | | Mendes, 1938 |

(Cont. Table)

| Kind of Coffee | Number of Chromosomes | | Author |
|----------------------|-----------------------|----------|----------------------|
| | <u>2 n</u> | <u>n</u> | |
| horsfieldiana | | 22 | Leliveld, 1938 |
| kapakata | | 11 | Leliveld, 1938 |
| liberica Hiern | 44 | | Heyn, 1936, 1938 |
| " " | | 11 | Leliveld, 1938 |
| " " | | 11 | Mendes, 1936 |
| " " | 22 | | Lebrun, 1941 |
| robusta Linden | 22 | | Heyn, 1936, 1938 |
| " " | 22 | 11 | Leliveld, 1938, 1939 |
| robusta x excelsa GP | | 11 | Leliveld, 1938 |
| stenophylla | 22 | | Lebrun, 1941 |
| ugandae Cramer | 22 | | Krug, 1936 |
| " " | | 11 | Leliveld, 1938 |

The knowledge of chromosome numbers may be usefully applied for further selection work. Referring to the studies by Frahm-Leliveld on chromosomes, Coolhaas (1939a, p. 557) remarked that from the crossing of *C. arabica* with 22 chromosomes with *C. robusta* or *C. congensis* with 11 chromosomes, hybrids with 33 might be expected. Without exception, when obtained they were poor yielders. Some hybrids have doubled the *C. robusta* participation of 11 chromosomes and had 44. These types were found to be better yielders, and might become valuable inasmuch as they could be traced by a cytological examination of the young seedlings in a nursery. In a later article, Frahm-Leliveld (1940, p. 380) gave further details on the cytological processes in the species and hybrids and advocated a broad plan for making hybrids of *C. arabica* with liberoid species, or with newer species introduced from Africa with the objective of obtaining rust-resistant forms with Arabica characteristics suitable for the middle and lower coffee belts. When a large number of such hybrids was grown for testing, it was possible to eliminate all plants with 33 chromosomes already in the nursery. This elimination would mean a considerable reduction in further work and in the requirement of land for further testing of the plants.

The chances that hybrids of *C. arabica* with other species will resemble the *C. arabica* parent are favorable. It has been found frequently that if a species with a high number of chromosomes is crossed with one with a low number, the characteristics of the species with the high number will be strongly dominant in the hybrid (Bremer, 1934, p. 159).

CHAPTER 26
HYBRIDS BETWEEN DISTANT SPECIES

SEEDLING VARIATION

It is not surprising that, in a genus as rich in species as is *Coffea*, a number of hybrids are found between these species. Some of these hybrids seemed to have a place in Indonesia among the commercially grown kinds, especially such as the hybrids of *Liberica* and *Arabica*, discovered in 1885 to 1900. Since the introduction of many new species in this century, other combinations have been used for commercial plantings. Some species such as *C. congensis* and *C. stenophylla* (Cramer, 1913, p. 610) were found to hybridize very easily.

As soon as the first hybrid was found, its multiplication by seed was tried, and since then seedlings of every new hybrid discovered have been raised. However, generally speaking, it was found (Kramers, 1898, p. 89) that generative propagation gave poor plants. They did not grow well, root systems were bad, and yield small. Sometimes they flowered profusely, but very few fruits set, and the seed did not germinate well. Several cases in which the garden in Buitenzorg raised seedlings from hybrids are mentioned in the *Verslag* (1892, p. 45).

Ottolander (1936, page 360) described seedlings of a *C. arabica* x *C. liberica* hybrid on Bandjar Sari Estate as resembling one of the parents or being more or less intermediate. He included drawings of some leaves. Since nothing was said about the yield, it was probably unsatisfactory.

It was apparent (Cramer, 1913, p. 33) that first generation hybrids obtained by the inter-specific cross showed differences among themselves, even when they came from the same parents. Among hybrids having *C. congensis* as mother and *C. ugandae* as a pollen parent, Cramer (1928, p. 36) found many different types, some of which seemed of practical interest. The later work in inter-specific crossing yielded many interesting hybrids among variable F_1 generations. It was also found that reciprocal crossings did not always give the same results with *Coffea*; with various families the influence of the mother was more pronounced than that of the pollen parent (s'Jacob & Hille Ris Lambers, 1938, p. 40).

Many experiments have been made with seedlings of hybrid trees. For instance, an experimental planting of a thousand seedlings was put out in 1897 (Maurenbrecher, 1900-1901, p. 577). The plants showed a wide variation. At $2\frac{1}{2}$ years a few had set fruit, but not profusely. Apparently all attempts to discover a hybrid which could be multiplied by seed failed.

Seed from hybrids on Indonesian estates were frequently received and planted at the Bangelan Station. In 1901 seed from chance hybrids on five Java estates were planted along with seed from Kawisari hybrids (*Jaarverslag s'Lands Plantentuin*, 1901, p. 103). In 1902 seed from a hybrid at Bandjar Sari Estate (*ibid.*, 1902, p. 82) were planted, and it seemed rather promising. In 1904-1905 seed from hybrid seedlings at Bangelan itself were used to continue the experiments (*ibid.*, 1904-1905, p. 117-119). On an estate in the Ranjoewangi district a planting was set out with seedlings of a splendid tree thought to be a *Robusta*. The mother tree proved to be a hybrid of a *Robusta* with a *liberioid*, and the seedlings were so poor that the field had to be replanted (Ultee, 1932b, p. 305). Kramers mentioned (1901-1902, p. 558) that among 5,000 seedlings raised by van Riemsdijk from seed of the Kalimas hybrid, three trees with satisfactory growth and yield were chosen for further multiplication by seed. Nothing further was ever heard of them. Hille Ris Lambers (1932, p. 26) tried to get a few superior trees from seedlings of both of the Kawisari hybrids B and D, and to ascertain whether there was segregation of characteristics. He found all kinds of deviant forms such as dwarfed plants, but none resembled a pure *C. arabica* or a pure *C. liberica*. Of the seedlings, 95 per cent were valueless for productivity but a few were kept for further study.

The hybridisation of an *Arabica* with a *Liberica* with *Maragogipe* was tried at Kandangan, and the seed were sent to Bangelan for testing (*Jaarverslag*, 1903, p. 131, and 1904-1905, p. 131). Hand crossing with *Arabica* was carried out with one Kawisari hybrid, and according to van Laer 1 seedling out of 10 obtained was considered promising and further propagated by grafting. Apparently nothing came from all these attempts to obtain valuable second generation hybrids as no such hybrids reached the point where they were used on estates for commercial planting or even for extensive experimentation.

The tendency of coffee hybrids to show great variability was discussed by Cramer (1907b, p. 289). Sometimes the seedlings of an *Arabica* hybrid showed characteristics not apparent in the *Arabica* parent but known in varieties of it, e. g., the *angustifolia* and *bullata* characteristics (Cramer, 1913, p. 225 and p. 239). Although the seedlings of interspecific hybrids always proved to be extremely variable, multiplication by seed was nevertheless attempted. Cramer (1907b, p. 286) thought that perhaps a stable form might be found by chance, and he recommended to planters that they raise a few seedlings of any spontaneous hybrid found. He explained how the hybrid could be studied for its practical value (1907b, p. 612).

There had been for some time a movement among the planters insisting that more attention should be given to coffee hybrids and their selection. Van Lennep (1899-1900) was one of the first to direct attention to the importance of hybrids for the planting industry and to the difficulties the planters had with them (p. 533). A year later Ottolander (1936, page 360) suggested that a special station for systematic hybridization of coffee should be established. These suggestions met with little success, probably because Robusta entered the scene about this time, offering an easier way to improve coffee production and doing away with the necessity for the complicated work of hybrid selection.

Lack of success in the multiplication of hybrids by seed forced the planters to resort to vegetative multiplication by grafting. Fortunately, it was found that hybrids lend themselves well to this method of propagation since they seemed to be more plastic than the pure species and, when used for grafting, united well with the other member of the combination. Therefore, the history of the techniques of grafting runs parallel with that of the hybrids.

HYBRIDS OF ARABICA WITH LIBERICA

Hybrids combining Arabica with Liberica or other kinds are not easily obtained because C. arabica is one of the few species with $2n = 44$ chromosomes, while most other Coffeas have $2n = 22$. Although Liberica and Arabica were often interplanted in Indonesia, spontaneous hybrids were comparatively rare. Several finds of such hybrids have been recorded in the literature. Mendes (1938, p. 8) spoke of two, one found by Bordage in Reunion and one found by Cameron in India; and still another from Ceylon can be added (Stuhlmann, 1902, p. 181). The oldest interspecific coffee hybrid known in Java has been the Kalimas hybrid, found in 1886 by Dessauvagie at the Kalimas Estate near Bodja, central Java. It was an intermediate type between Arabica and Liberica. The broad, leathery leaves are like those of Liberica, while the fruit, with its juicy pulp and soft skin, resembles the berry of Arabica. The resistance of the Kalimas hybrid to leaf disease has long been known. Its history has been told by Ottolander (1936, page 360, cited from De Landbouwer of 21 May 1888). In 1886 Dessauvagie found a plant in the nurseries resembling Liberica. It was planted as such but in 6 months time proved to be different. In 1888 the fruit ripened, and the pulp proved to be soft like that of Arabica, but the leaves had the size and texture of those of Liberica.

The discovery of the hybrid in Kalimas Estate "on an estate in central Java", in a nursery of Arabica was recorded in 1896 by van Romburgh and Wigman (see Ind. Mercur, 1898, p. 254). Kramers (1898, p. 90) also stated that the hybrid was found in a nursery of Arabica and was planted in the garden of the assistant's bungalow. It was still there about 1918. From this plant van Riemsdijk took a few branches as graftwood, and this was the original material for establishing the large plantings of hybrid coffee at Klein-Getas. From these dates it seems clear that the Kalimas hybrid corresponds to the cross C. arabica x C. liberica.

The supposition that all spontaneous hybrids of C. liberica and C. arabica have C. liberica as mother (Ind. Mercur, 1893, p. 327) is erroneous. Spontaneous hybrids between the two species were more frequently seen among seedlings from C. liberica, but occasionally a plant was found in nurseries of C. arabica which, by its whole appearance, showed characteristics that were intermediate between the two species and which, therefore, could be considered a hybrid (Kramers, 1898, p. 89). Wigman (1890, p. 270) mentioned a spontaneous hybrid in a field of Liberica. He also described hybrids of C. liberica with C. arabica var. menado as pollen parent and the reciprocal cross, both obtained by artificial pollination, from trees standing next to one another in the Cultuurtuin (Wigman, 1890, p. 271). Each hybrid resembled the pollen parent.

The taste of the product of these hybrid coffees has often been praised. Local connoisseurs have been said to prefer it to Robusta. It is claimed to unite the strength, "body", of the Liberica with the aroma of the Arabica, and small lots often obtained a premium on the local market. The appearance of the beans was considered rather unattractive. The color was not generally even, but mottled (Anon., 1907, p. 783). However, the value of the coffee hybrids as resistant and productive forms was soon realized. In 1899 at the Coffee Conference in Djocja, s'Jacob (1899, p. 870) advised the planting of Liberica-Arabica hybrids.

A few years later van Laer (1904-1905, p. 96) recommended these hybrids to the planters. Further, it seems that Peereboom Voller (1904-1905, p. 967) recommended Kalimas hybrids for east Java, mentioning that planters were often prejudiced against grafting by disappointing experiences with Arabica grafts. A yield of 6 q./ha. was recorded in 1904 and 1905, a proportion of 8:1 and a price of 28.5 cents per half kg. in Rotterdam, equal to the price for superior Liberian coffee, although the product after the hulling was uneven in color. When it was stored for some months and then passed through the huller again along with the debris of the parchment skin in order to polish it, the appearance was improved.

In a later article it was reported (1904-1905, p. 987) that prices of 26.5 cents and 33.25

cents were obtained in Rotterdam, along with the opinion of an expert who called the flavor good and pure. Peereboom Voller reported having received 29.5 cents for his hybrid market coffee and 32 cents for the round bean.

In 1910 Cramer (1910b, p. 870) compared Robusta and the hybrid coffee to Arabica and Liberica on various points such as costs, yields, disease resistance, and quality. He explained the merits of the hybrid as a stable, reliable producer. Wurth (1915, p. 880) confirmed Cramer's opinion of hybrids and added more recent yield figures gathered by him.

About a decade after the discovery of the Kalimas hybrid a group of analogous hybrids appeared. The first description of these was contained in an article by s'Jacob (1899-1900, p. 488) in which he stressed the importance of hybrids for regenerating the coffee planting industry, then at a very low ebb. He described two hybrids without adding the name of the estate. However, a note in the Verslag (1901, p. 119) stating that s'Jacob sent seed of the well known hybrid to the garden indicates that it was Kawisari. The same hybrids were mentioned by H. S. (1900-1901, p. 142). Further data on these hybrids, found by Everard among seedlings of Liberica, were given by Cramer (1923, p. 570). Out of four hybrids, two, B and D, were selected as the most valuable and used for field grafting on old unproductive Liberica trees which were converted by this method into good yielding grafts. Grafts were also made in the nursery.

Kawisari B was found in nurseries of Liberica planted with seed from Gemampir in 1896. Set out in 1897, the tree yielded 4.3 kg. berries in 1898, 15 kg. in 1899, and afterwards, in spite of the fact that it was used for producing graftwood, it still gave yields of 600-1,200 g. per annum.

Kawisari D was found in a nursery with plants raised from Liberica seed from the estate of Kawisari itself and was transplanted in 1899 as a young tree just beginning to branch. In 1903 this tree gave a first yield of 1.5 kg., with 6 to 7 per cent empty beans and a proportion ranging from 5:1 to 7:1. The skin of the berry was thinner than that of B, and the bean showed more resemblance to Arabica beans.

Kawisari A I, was obtained by Everard from artificial crossing of Hybrid A, not further used, with pollen from Arabica. From this, 10 plants were obtained, of which 9 were attacked by leaf disease. The one plant not attacked was transplanted in December 1900. In 1903, then in its third year, it yielded 600 g. market coffee. The percentage of empty beans was only 6 per cent, and the proportion was 6:1. The tree showed a beautiful branching habit, but it was not easy to graft, a fact attributed to the increased Arabica element. The growth of the grafts was slow. Van Laer (1904-1905, p. 102) mentioned similar hybrids from 3 other estates, but they never found commercial application.

The market product of the hybrid showed a mottled color, and flavor was not as strong as that of Arabica, but superior to Liberica. In other coffee producing countries the Kawisari hybrids seemed to do well. Kawisari B, grown at an altitude of 8 meters in the garden of the College of Agriculture, Philippine Islands, did not show any signs of attack by rust caused by Hemileia rust and gave a very satisfactory initial yield (Mendiola, 1931, p. 111).

To these standard hybrids a few were added at Bangelan, such as Hybrid Soember Sengkareng and Hybrid Soember Telogo. All these Liberica-Arabica hybrids proved to be less productive than Kawisari B and D. The Soember Sengkareng hybrid at Bangelan gave an average yield of 548 kg./ha. over a period of 11 years. This is under the average for the Kawisari hybrids (Ferwerda, 1935, p. 21, Table 2). The average yield for a 10-year period for Kawisari B was 669 kg./ha.; and for Kawisari D it was 744 kg./ha., the best yielder of this group. A characteristic of most hybrids with Liberica was that the berries remained well fixed on the branches and did not drop easily, an advantage when picking was later (Cramer, 1924b, p. 230).

HYBRIDS OF ROBUSTA WITH LIBERIOIDS

The second group of hybrids somewhat similar to those just discussed, is composed of hybrids obtained by combining liberioid species with Robusta. When I was on trips visiting estates, sometimes I heard of the discovery of an abnormal tree and found upon inspection that it was a spontaneous hybrid. As a rule some graftwood was cut and sent to Bangelan. Several Liberica-Arabica hybrids were discovered in this manner, as was a seedling in a planting of Robusta grown from seed from an estate where Excelsa had also grown. In another case a hybrid was traced among the seedlings on Bangelan itself (Robusta 78.13). Of the several Robusta-liberioid hybrids, the most interesting was the QP., apparently a cross between Robusta and Excelsa introduced by me at Bangelan from an estate on the Keloed mountain. It was somewhat similar to the other group of hybrids in its leathery, very dark leaves, vigorous growth, and resistance to leaf disease. It had, moreover, the virtue of standing very moist climates well. The ripe berry did not drop easily but remained fixed to the branch for several weeks. The QP. hybrid does especially well in moist climates, for

instance, in the Cultuurtuin at Bogor. It was considered very promising for southern Sumatra. There were indications that it suffered less from berry borer as the beetle remained in the pulp of the fruit (Heubel, 1939, p. 776). A year before it had been described as doing well there, together with a few Robusta clones notably BP.42, and Mb.III.04 (Heubel, 1938, p. 685). In contrast with the former group of hybrids, the clone was found to be self-incompatible, but even so the yields of monoclal plantings were satisfactory. A yield of over 10 q./ha. was obtained at Bangelan for 3 years (Ferwerda, loc. cit., Table II).

STENOPHYLLA HYBRIDS

As previously noted, *C. stenophylla* is known to hybridise easily, especially with liberoid species. The Cultuurtuin had a hybrid *C. stenophylla*-*C. abeokutae* in its clone collection, and it was one of its most vigorous clones. It was Hemileia-resistant but bore only a few berries per node and therefore was not very productive. The flowers had 8 lobes, and the berries were black, as with the mother. The *C. affinis* described as a separate species must be considered a hybrid because of the way it was found. On the Ivory Coast hybrids of *Stenophylla* with *Liberica* were frequently found in plantings of the gros Indenié. It was more resistant to drought than both of its parents and fairly productive, but the beans had an unpleasant appearance (Sibert, 1932, p. 76). Similar hybrids were introduced into Java from Singapore as seed. The plants showed a great variability. Some were nearly pure *Liberica*, others nearly pure *Stenophylla*, the rest were of intermediate types (van Hall & van Helten, 1917, p. 36). None of these hybrids developed any commercial importance.

CONGENSIS HYBRIDS

An interesting group is the hybrids between *Congensis* and the robustoid species. These were found by me among seedlings at Bangelan or identified by me as such among my introductions in the Cultuurtuin. Several trees of *Congensis* obtained in 1903-1907 were set out in the Cultuurtuin. Some graftwood from one of the best trees was taken in 1909, and with this material grafts were made on shoots of some stumped *Robusta* trees at Bangelan (Cramer, 1913, p. 695). Next to one of these grafts, another was made with graftwood that had also been received from the Cultuurtuin, from one of the original *Uganda* trees. The branches of the *Congensis* graft and of the *Uganda* graft were intermingled. Both started to bear fruit in 1912, and some of the first seed of both were used for establishing a small experimental planting of both species in 1912 (Jaarverslag Bangelan, 1913, p. 56, Table G).

In the field planted with *Congensis* many trees were found to be poor growers, and they were replaced by grafts of the mother tree on *Excelsa*. On inspection of the field in 1913-1914, among the seedlings some trees were found with darker, broader leaves and larger berries, giving a fair yield. From the way the mother tree had been exposed to pollination by the neighboring *Uganda* graft it was concluded that they were hybrids, corresponding to the cross *C. congensis* x *C. ugandae*. The field which by chance had been planted with the seedlings of the neighboring *Uganda* graft was also examined and found to contain several trees differing from *Uganda* and closely resembling the broad-leaved ones in the *Congensis* field. These were considered to represent the reciprocal cross.

In contrast with robustoid species, the fruit stalk of *Congensis* was known to be about 7 mm. long, and thus the fruits were in looser clumps and not pressed together (de Wildeman, 1905-1907, p. 337). This characteristic would appear to give *Congensis* a resemblance to *Arabica*. In all *Congensis* hybrids this characteristic was found to be conspicuous.

Plants were then examined that had been raised from seed introduced from Madagascar as *C. congensis* var. *chalotii*. From a comparison of the characteristics of both species I also concluded that variety *chalotii* was also a hybrid, but in this case *C. congensis* x *C. canephora*, because it presented several analogies with this last named species. It was found that other material received from Madagascar under the name of *C. congensis* was also probably of a hybrid nature, since the trees did not present the poor growth, yellowish leaves, and very small berries characteristic of the pure species introduced in the same period. When other introductions of *Coffea* were examined, a collection received in the Cultuurtuin under the name of *C. canephora* var. *kouilouensis* was found to resemble the *Congensis* hybrid in its foliage, long soft juicy berry, and dense growth. Two clones of it, probably from mother trees introduced by me in 1907 from the Serres coloniales in Laeken near Brussels, were preserved. The history of these clones cannot be clearly reconstructed from the data in the publications of the Cultuurtuin. In van Helten's "Gids" (1918) it is stated that five seedlings of an introduced tree of the variety *kouilouensis* in the Tjilendek garden were put out on 3 April 1912 in Field B I 465 Cultuurtuin, and that from these five trees -- the first generation in Java -- grafts were made and planted in April 1917, enumerated as "grafts from introduced trees No. 465/103 April 1917", etc. (van Helten, Gids, 1918, p. 50).

In van Hall & van Helten's list (p. 23, 1917) none of these trees or plantings were mentioned,

but some "introduced trees" in the Tjilendek garden were said to have been used to make grafts. The two clones long held in the Cultuurtuin collection may have been derived from them or from the trees introduced in 1907 from Serres Coloniales, Laeken. In any case they showed a strong resemblance to Congusta hybrids and were exceptionally luxuriant growers. Seedlings of these trees were found to be of no value. However, they are comparable with the seedlings of Congensis hybrids discussed below. Only a few good trees have been taken from them and kept in the Cultuurtuin. Among these was one which must have been a hybrid with *Stenophylla*. Since the introduced material came from experiment stations it seems quite possible that hybridized seed or plants were obtained.

In 1915, as soon as seed of the material at Bangelan was available, small plantings were set out of seedlings of the trees called Congensis hybrids. It was expected that seedlings of these would give good producing, although not uniform plantings (Cramer, 1916c, p. 403) comparable with the offspring of a hybrid such as Robusta Bgn.124. They included seedlings of *C. ugandae* x *C. congensis* (2.11-2.13), *C. congensis* x *C. ugandae* (2.01-2.06), and a Robusta, No. 104.11, a tree resembling to some extent the hybrid Congensis mother trees (Jaarverslag, 1915, p. 59). When these gave a crop they were found to be poor yielders, often with very small seed. A good tree among them was an exception. During 1916-1917 small plots in the clone museum, then started at Bangelan, were established with grafts of the Congensis hybrid mother trees. The young grafts of the hybrids *C. congensis* x *C. ugandae*, and the reciprocal cross, were already described in 1917 (Jaarboek, 1917, p. 49) as fast growing and early flowering. They were considered to be more promising than the seedlings of these hybrids, which appeared extremely variable.

In 1918 somewhat larger plots of some of these clones were planted. Three years later, when the various grafts had started producing, they were considered so promising that it was decided to plant the best of them on a semi-commercial scale and to graft them on different stocks. By the end of 1924 this plan had been carried out. Also in 1924 they were first recommended for experimental planting (Cramer, 1924, p. 42), especially as a second kind suitable in addition to Arabica for estates in higher altitudes.

This recommendation had already been put into practice in commercial planting. In 1919 a progressive planter of the Malang district, Celosse, manager of Soember Agoeng Estate, visited Bangelan and heard of my hybrids of Congensis as being suitable for higher altitudes. He ordered budwood at once and grafted it onto three-year-old Excelsa on his estate. In the following years these plants were extended (Celosse, 1934, p. 288). These were the oldest commercial plantings of the hybrids, by mere chance on the same estate where the first introduced Robusta was planted.

In 1928 I described (see Cramer, 1928, p. 36) the material I had introduced from Madagascar under the names "*C. congensis* Madagascar" and "*C. congensis* var. *chalogii*", as probable hybrids, and indicated that this last variety probably had *C. canephora* as a pollen parent. The history of *C. congensis* var. *chalogii* Pierre is described by Dubard (1908, p. 363). Chevalier and de Wildeman thought it was a variety of *C. canephora*. Chalot introduced it into the experimental garden in Libreville and sent seed to the Jardin Colonial, from which young seedlings were sent to Madagascar. It was introduced there in 1900 and where E. Prudhomme found it to be resistant to Hemileia rust (Dussert, 1910, p. 337) in 1903.

The variety Chalogii was introduced in 1908 into the Economic Garden in Buitenzorg. A quantity of seed was received from the Agricultural Service in Madagascar, and germination was very satisfactory (Jaarboek, 1908, p. 86). From this history it appears that the seed received in Java may have been hybridized by *C. canephora* in Madagascar. This does not mean that the original *C. congensis* var. *chalogii*, as it was found in the forests of the Belgian Congo, was already a hybrid. However, it is possible that such was the case (See de Wildeman, 1901, p. 17).

The quality of the market product of "*C. congensis* var. *chalogii*" was judged equal to good quality Santos coffee (Fauchere, 1910, p. 1). It obtained a certain popularity in Madagascar, but since Kouilou coffee showed sufficient resistance to rust there, the former variety had been given up as not sufficiently productive (Fauchere, 1919, p. 267).

In the meantime the hybrids had been described between Congensis and Uganda which I had found about 15 years earlier. Thus were recognized 4 groups of presumed Congensis hybrids: (1) the kinds I introduced under the name "*C. congensis* Madagascar" and (2) *C. congensis* var. *chalogii*; (3) the hybrids *C. congensis* x *C. ugandae*; and (4) the *C. ugandae* x *C. congensis* I had traced in the field at Bangelan. It was suggested that these 4 kinds should be called "Congusta" coffee, and the second part of this name was to signify a robustoid species, not pure *C. robusta*.

In 1934 Ferwerda (1934a, p. 601), using the same classification but putting the last two groups together, changed the original names of all these hybrids into the so-called "Conuga coffee". It must be understood that the kinds so named included, in addition to the combination of *C. congensis* with *C. ugandae*, hybrids which did not contain *C. ugandae* blood, but *C. canephora* and perhaps other

kinds as well. For this reason the name seems less appropriate. Moreover, in 1936 an expert in Holland suggested that it would be wise to drop the name "Conuga" and to export the product under the name "Java" because the roasters had unpleasant experiences with "Conuga" (Coolhaas, 1938, p. 189). But apart from these minor reasons, it seems that the name the originator of these hybrids gave to them, "Congusta coffee", had the right of priority and should be kept.

In appearance the Congusta hybrids resembled the *C. congensis* parent more than the robustoid parent. Under conditions in Indonesia, the growth was fairly rapid, and the branching dense. The branches were thin and flexible, and when they would droop on topped trees they formed a narrow tree with abundant fruit-bearing wood. As a planting distance, 2.7 x 2.7 m. was originally chosen, but this was found to be too wide. The berries were oblong, medium sized, narrow, some times pointed, and often very dark green when unripe. The ripe berries have a thin skin and, when ripe, of different shades of red with the various clones. Freshly pulped beans were white, like those of Arabica. The yield was good, although the number of berries per node was not as great as it was with Robusta, but the internodes were short and the branches loaded with fruit.

In general, these hybrids somewhat resembled Arabica. The proportion of berries to market coffee was about 5:1, if there had not been any extensive berry borer damage. The market product was of good appearance, green, oblong, narrow beans, with those of some clones resembling Arabica. The percentage of round beans was found to be high. The flavor was better than that of Robusta, more delicate, with more aroma. Leaf disease was rare or absent, but scale damaged the trees, especially during intensive drought, although the drought itself did not do much harm to the trees. The longer fruit stalk and looser fruit seemed to make the Congusta forms less susceptible to dompolan lice (Betrem, 1932a, p. 559). The most serious pest of Congusta was the berry borer. The thin fruit skin and parchment skin and the juicy fruit pulp appeared to make the berries very attractive to the beetle. The trees seemed to flower practically the whole year round. The ripening of the crop started early in the year, and there was often a late crop also. This habit favored berry borer infection, which could be very serious at altitudes below 800 m.

Although little was heard about the new hybrids before 1932, they seem to have attracted the attention of planters, mainly because some experimental plantings on estates gave very good yields in contrast with Robusta. Ultee (1932b, p. 308) advised the inclusion of the new hybrids in clone testing plantings, but he warned planters against expecting too much or planning a general replacement of Robusta by *Congensis* hybrids. Shortly afterwards Schweizer (1932, p. 455, table for Kali Telepak) published some yield figures for these hybrids at Kendeng Lemboe, where in 1931 clones 161 and 2.03 yielded 29.8 piculs per bahoe, equal to about 26 q./ha. nearly double the yield of the commercial Robusta plantings. About the same time Ferwerda (1932, p. 644) considered some of the clones very promising.

The first practical planter who took up the *Congensis* hybrids, Celosse, was also the first to publish his experience with the new kind (1934, p. 288). After explaining how he came to plant it by hearing of these hybrids of Cramer's during a visit to Bangelan, he recorded the results the grafts gave on his estate. In 1933 the yield was 11.66 piculs per bahoe (10 q./ha.) and promised to be the same in 1934. A planting distance of 2.5 x 2.5 m. and a topping height of 3 m. were advised. Celosse preferred Robusta Bgn.124.01 as stock as it was resistant to nematodes, a danger on his estate. The crop of these hybrids was distributed over the whole year. The berry borer did less damage on it than on Robusta, and the branch borer did no harm. The berries were easy to pulp and gave a clean product of good appearance which contained on the average 39 per cent of round beans.

In a later note (Anonymous, 1934, page 630) some favorable reports on the quality of the product are cited, and it was noted that a price of 17 cents per kg. was obtained, in comparison with 15½ cents for Robusta. In 1938 the Malang Institute reported on the quality of Congusta coffee (Coolhaas, 1938, p. 188), from a report of 1936 on two samples from Celosse. The taste of one was called fairly good, of the other good. The high content of round beans was mentioned as an undesirable characteristic. In a later shipment the round beans were removed, and the taste was considered improved. The new kind was mentioned as suitable for blending because the taste was strong (p. 188). A statement from two offices in Soerabaja pointed out that reliable information on the value of the new kind could be given only when it would be regularly obtainable, as only under such conditions could the large roasters use it for their blends (p. 189). Celosse added that he cured the coffee by fermenting the beans 60 hours, and drying them for one day in the sun, with 40 hours in the drying house. The most profitable way to sell the round bean was to add it to second grades, which then obtained better prices. The Congusta from Soember Agoeng sold in Holland for about 10 per cent more than Robusta, and as far as known, went to Scandinavia for consumption.

The favorable opinion on the quality was later confirmed by two experts who participated in judging the samples prepared by Roelofsen (1939c, p. 271) for his testing of various clonal coffees. They called the taste "good", but a third described it as "nasty". The beans came from Congusta

clone SA.36. The average weight was 192 mg., and the color was "normal yellow".

After the recommendation of the new kind by a planter, based on his experience, more was heard about it. The first article was the attempt of Ferwerda to give the new kind a new name, *conuga* (Ferwerda, 1934a, p. 601). In 1935 some data from Cramer's plantings at Bangelan appeared with notes on the characteristics of the various clones (Ferwerda, 1935, p. 19).

Congusta has withstood all adverse conditions well. For example, a clone which gave satisfaction on a very high, moist estate also did well in another region after an intensive drought and an attack of white lice, while Robusta next to it bore practically no fruit. In 1938 data from Malang Sari, an estate in a moist climate, were published by the manager, de Ligt (1938, p. 972). After an experimental plot dating from 1924-1925 on Malang Sari had given promising yields and shown a proportion figure of only 4.5:1, a small extension with the new kind was made in 1931. In 1934 it yielded 4.35 q./ha. Some data on yields from other estates showed figures surpassing those for Robusta. Other estates reported simply that the hybrid gave 2 or 3 times the yield of Robusta, and these were all estates in a moist climate. De Ligt gave several useful hints. A good market quality was obtained by spreading the beans immediately after the washing on a concrete floor for a preliminary drying and then drying them in the drying house at a low temperature. The color was yellower than it is with Robusta, and the product obtained a good premium above the Robusta price.

Soon afterwards de Ligt (1939, p. 726) published further information on the merits of the new kind. The narrow shape of the tree, its habit of profuse branching, and its great resistance to branch borer rendered it attractive to the planters. Planted in 2.5 m. squares, trees keep their branches well and develop into good yielding columns. The pruning system, sometimes applied with Arabica, whereby a shoot is allowed to develop on the undertree until the undertree suffers, was suitable for this kind. A planting established by grafting in the field on one-year-old stocks in 1931 yielded 4.35 q./ha. in 1934 with subsequent annual crops ranging from 10 to 18 q./ha. On a wet estate with 3.5 m. rainfall and no dry season, it yielded in 8 cropping years an average of 16 q./ha. against 4.05 q. for BP.42. The various clones of the Congusta all gave satisfactory yields; Bgn.2.03 and 161 were among the best. As stocks, Robusta Bgn.124.01, Excelsa, and Arabica have all given good results. The resistance to nematodes of grafts on 124.01 has been discussed.

Somewhat later a new kind obtained a place in Indonesia on the list of interesting material for grafting. In 1941 five clones, numbers 2.03, 4, 6, 161, and SA.36, were placed on the list of material recommended for large-scale testing. Eventually no. 2.14 could be added (Snoep, 1941a, p. 408). This judgment was given after the yields had been studied in a series of clone testing plots where they could also be compared with Robusta clones. The yields were of the same order. The data indicated that Congusta could not reach the yield level of the best Robusta clones on the dryer estates in the middle belt. However, it had qualities that justified a preference for it -- low susceptibility to dieback of top, suitability for rejuvenating old Robusta trees, and recuperative power after overbearing. For the higher and moister estates the Congusta clones were considered promising even in comparison with the best Robusta clones. A few remarks on the size of the beans mentioned Congusta Bgn.4 as belonging to the large beaned types, followed by Bgn.2.03 and 2.09 (Snoep, loc. cit., p. 408). In the Cultuurtuin at Buitenzorg Congusta 2.08 showed very large beans, resembling those of Arabica in shape.

When a mixture of clones was planted to improve cross-pollination, yields of Congusta at Bangelan fluctuated around an average of 12.5 q./ha. of market coffee, a figure which competed with yield of the best Robusta clones (Ferwerda, 1941, p. 565). This indicated the merits of Congusta for a place outside the moist climate of the higher altitudes.

Hille Ris Lambers (1936, p. 597) made crosses of Congusta SA.36 with BP.42 and the reciprocal cross with brilliant results. He found that the size of the berry was equal to or surpassed that of BP.42. Two of these hybrids were included in the test of the quality of the product of various clones. The beans had an average weight of 210 mg. and 208 mg., against 256 mg. for BP.42. Both produced beans with the form of Arabica beans, and the taste was considered good (Roelofsen, 1939c, p. 270). There has been some commercial production of Congusta. For example, in 1938 the total for Java was 699 q., and in 1939 it was 2,751 q. (Anonymous, 1941, p. 146).

These hybrids also began to attract attention in other coffee producing countries. In Madagascar *C. congensis* x *C. canephora* hybrids with a high yield became available: The product obtained a premium above the price paid for Kouikou at Le Havre (François, 1939, p. 162).

HYBRIDS OF ARABICA WITH ROBUSTOIDS

There is a further group of hybrids, the combination of *C. robusta* with *C. arabica*. The oldest representative of this group is the "Bogor Prada Hybrid", introduced at Bangelan in 1914 (Jaarverslag, 1914, p. 98). A seedling of *C. robusta*, the plant revealed at once by its characteristics that a Maragogipe standing near the Robusta mother was the pollen parent. Its origin is mentioned

and given correctly by Cramer (1924b, p. 231). The description of its origin in van Helten's list (1918, p. 51) is erroneous. This hybrid had the broad convex leaves of Maragogipe, but brighter in color than those of ordinary Robusta. The hybrid showed exceptionally vigorous growth and developed into a densely-leaved tree. It was hoped that the combination with the highly flavored Maragogipe would render the market product superior in quality; but when the beans, which were larger than those of ordinary Robusta, were submitted to an expert, no material improvement over Robusta was found. The crop per hectare was too small for profit at ordinary Robusta prices. Seedlings showed the common, extreme variability of their class and produced valueless trees.

A few spontaneous hybrids from chance crosses between C. robusta and C. arabica were obtained by Cramer by sowing seed from C. robusta trees standing isolated in large C. arabica plantings. The trees developed dense branches with beautiful, healthy foliage, practically free from leaf disease, but the yield was very low.

Reciprocal hybrids have been obtained by Schweizer and in the future, may become of considerable interest for commercial planting. The original aim in producing these hybrids was to obtain forms suitable for the lower Arabica belt. The cross was made by Schweizer in 1923 by pollinating mother trees of the Arabica variety "Java Pascoemah" on the Pantjoer Estate, with pollen taken from grafts of Robusta BP.39 and 42 at Kaliwining. Crosses were also made of the Pascoemah coffee with Congusta. The difference in flowering time and the long distance separating the pollen parents from the mother trees presented some difficulty. The Robusta at Kaliwining flowered on 10 November 1923, the Pascoemah at Pantjoer on 25 November 1923 (Arisz, 1924, p. 40). The crossing was fairly successful, and about 60 hybrids were planted. Six years later Schweizer was hopeful that they might be resistant to leaf disease (Dinsdag, 1929, p. 5). In the preceding year they had been put under mosquito netting, and they were expected to yield a good quantity of F₂ seed in 1929 (Gandrup & Schweizer, 1931, p. 52). However, the legitimate autopolinations under mosquito netting produced no seed (Schweizer, 1932a, p. 56). In order to obtain quicker results with the hybrids, grafts were made from them in Djember, in the low plain, and planted in the garden of the Research Institute. These grafts showed a much faster growth than the trees on the Idjen plains, and they also promised an earlier fruiting (Schweizer, 1931b, p. 47).

In 1932 exceptionally heavy flowerings were reported for the hybrids, but very little fruit set. This was found to be the case at Kalisat on the Idjen plain as well as on an estate in the Robusta belt and at Djember. The question was studied more fully, and it was found that in the first 2 or 3 months after flowering the small fruits remained on the branches without swelling. The shedding of the small fruits was found to begin and continue for 5 or 6 months after which there were very few fruits left, but all of the latter attained normal development. The progeny from the trees in the F₁ planting, which showed pure Arabica characteristics, all appeared to be pure Arabica. Tested under various conditions on estates, these showed no hybrid characteristics. The progeny of the true hybrids were abnormal, deformed plants, but when somewhat older, some developed into decent trees (Schweizer, 1933a, p. 69). The shedding was studied further. It was found that the development of the embryo sac stimulated the berries to swell, but the failure of fecundation prevented further development and caused them to drop (Frahm-Leliveld, 1938b, p. 148).

Schweizer went on with his hybrids, applying back crossing with Arabica. It was then found that some of the hybrids of a later generation, maintaining the Arabica type, stood the low country conditions well and yielded a product similar to Arabica. The caffeine content of the bean was found to be a hereditary factor (Jaarverslag, 1940, p. 231). When two species with different numbers of chromosomes are crossed, it appears that the characteristics of the parent with the larger number frequently predominate (see Bremer, 1934, p. 149). The Arabica characteristics gave these hybrids particular value. The original problem of finding a form suitable for the lower Arabica belt had been previously solved by using the Abyssinian Arabica in this region, and thus, for this purpose, these induced Arabica hybrids lost some of their importance. However, there was renewed interest in their suitability for the low country, and they have been tested at various altitudes (oral information from Schweizer).

Similar crosses were made by Hille Ris Lambers (1933, p. 1411) between C. arabica and C. laurentii to produce the "Arla" hybrids. In the beginning these hybrids looked promising. They showed a higher resistance to rust than pure Arabica, and the growth was more vigorous. However, the yield was disappointing. In the study of samples of this coffee by Roelofsen (1939c, p. 271) the market product of an Arla hybrid (no. 1) was included. The beans averaged in weight, 2.48 mg. They were fairly large, grey and spotted. The verdict on the taste was rather unfavorable with remarks such as, "like Liberica", bad, and very bad. In all these Arabicas with 44 chromosomes x Robustas a species with 22 chromosomes, the C. arabica was combined with one with 11 chromosomes. Most of the hybrids developed by Hille Ris Lambers did not set any fruit, or did they give a very high percent-

age of round beans. Only after a long period of research was it possible to single out three trees as promising, viz., Arla 1, 6, and 16. The first had as diploid numbers 22, 44 and 88 chromosomes in the nuclei of the root cells. In Arla 16, 44 chromosomes were found according to Frahm-Leliveld (1938, p. 853). This was a good type. The number for the poor yielding types was found to be 33.

In Brazil the same group of hybrids has been studied with similar results. Hybrids of the C. arabica varieties, Bourbon and Mokka with C. canephora (robusta) were produced by Krug, and the cytology of the crosses was studied by Krug and Mendes (1941, p. 480). The hybrids were intermediate between the parents. They were triploid and sterile, but two seedlings, which had $2n = 44$ chromosomes, were obtained from a triploid tree from uncontrolled pollination by surrounding coffee trees. Autopollination of flowers of the triploid trees and hand pollination with pollen of C. arabica and C. canephora did not produce seeds.

Schweizer (1931a, p. 58) mentioned hybrids of C. arabica with C. congensis as pollen parent in addition to the hybrids of Arabica with BP. Robusta. These hybrids resembled Arabica, and the berry was seen to be very similar to that of Arabica. Productivity was good, and taste near to Arabica. Trees of the C. arabica x C. congensis hybrids were like Arabica in characteristics of leaf and berry. However, growth was more vigorous, and, at the time of writing, they had remained free from leaf disease. A few words on the chromosomes of the F_2 of these hybrids, crossed with C. arabica, may be found in a study by Frahm-Leliveld (1940, p. 386).

KAPAKATA HYBRIDS

As a curious interspecific hybrid, the combination of Kapakata coffee with some robustoid species has already been mentioned. Kapakata x Robusta, Robusta BP.42 x Canephora Madagascar, and Robusta x Uganda Bgn.1°, have all been successfully obtained by Hille Ris Lambers. The crossing of Kapakata 1 x Uganda Bgn.1° x BP.42 was also carried out. Some of these plants resembled Uganda and lost entirely the resistances to the branch borer in the F_1 , Kapakata 1 x Uganda Bgn.1° (Frahm-Leliveld, 1940, p. 386). One could almost say that the two closely allied species, Robusta and Ugandae, joined hands, easily settled their quarrel over their chromosome situation, and pushed out the troublesome outsider, Kapakata.

The verdict on the product of the hybrid Kapakata x Canephora was unfavorable, although it was better than that on Kapakata itself. The beans were very small, and rather yellow. The taste was extremely bad, although better than that of pure Kapakata coffee (Roelofsen, 1939c, p. 272).

CHAPTER 27
HYBRIDS WITHIN THE GROUP

As a last class of material of practical value some hybrids between species of the same group or between varieties of the same species must be mentioned. Generally speaking, they do not present the difficulty of weak growth and very poor yield in their seedlings, the F₂ generation which is found in interspecific hybrids. Sometimes group hybrids are quite successful when reproduced by seed.

ARABICA GROUP

As an example of hybrids between two kinds belonging to the same group, can be mentioned the C. arabica var. mokka x C. arabica var. typica described by Cramer, (1913, p. 163). In growing habit in Indonesia these hybrids resembled the Mokka variety. The dimensions of the various parts of the plant such as length and thickness of the internodes, size of leaf, of flower, and of berry were intermediate between the characteristic dimensions of the two parents. The F₂ generation raised from seed of these hybrids showed a greater variability. Some plants looked like pure Mokka, with others like typical Arabica. All intermediate stages could be found, and Cramer (loc. cit. p. 168) also mentioned a case of "bullata" plant resembling those found among seedlings of certain Arabica x Liberica hybrids.

Spontaneous hybrids have occurred among forms of C. arabica. The Mokka variety has apparently hybridised with typical large beaned C. arabica, producing the so-called "Mokka large bean" (Cramer, 1913, p. 163).

Interesting spontaneous hybrids between two forms of Arabica have been found in Puerto Rico. They apparently corresponded to the Arabica varieties San Ramón x Maragogipe. The hybrids exhibited the growth characteristics of San Ramón, showing short internodes and dwarf stocky development, while in size of leaves and fruit they were more similar to Maragogipe (McClelland, 1924, p. 13). A cross of Mokka with Maragogipe obtained in Queensland was reported (see article on coffee mentioned in the Kew Bulletin, 1894, p. 164).

A hybrid Bourbon x Maragogipe was mentioned by Laliere (1909, p. 40), citing a report from G. d'Utra, who considered it a form with a high, more regular and more certain yield, and therefore promising.

The hybrids between various forms of Arabica more recently being studied by the Campinas Institute in Brazil have been recorded. Mendes and Krug (1938) mentioned crosses Bourbon x Maragogipe, Mokka x Maragogipe, Nacional x Laurina, and Bourbon x Nacional. Each of these four hybrids yielded more than the progeny of the autofecundated parents. The preliminary results with these hybrids are encouraging, not only with respect to yield but also with respect to resistance to dieback, mainly among those of the Maragogipe variety.

LIBERICA GROUP

Hybrids within a group have also been found among the liberoid species. A few C. excelsa x C. liberica hybrids found by Cramer were outstanding in vigor and yield, but they never passed the experimental stage because there was little interest in Liberica. To this group belong Excelsa 1 and 4 from Tjilendek Estate, included in the collection of the Cultuurtuin. The original trees 1 and 4, were raised from the first seed from an introduced Excelsa tree standing near Liberica. The seed was planted in the Tjilendek garden. The resultant trees were later erroneously mentioned by van Hall and van Helten (1917, p. 33) as "introduced" trees.

Spontaneous hybrids of C. dybowskii have also been recorded by Ultee (1922, p. 18). Seedlings, apparently from Dybowski crossed with Liberica, did well at Kaliwining.

ROBUSTA GROUP

Hybrids between closely allied sub-species have not been rare in the Robusta group. Species such as C. ugandae and C. robusta cross easily with one another. Among the first seedlings obtained from the introduced C. robusta there was one called Robusta Bgn.124, which was of outstanding vigor and endurance in situations where there was deficient shade. Its characteristics appeared as a mixture of those of the parents, C. robusta and C. quillou. In growing habit it was like Quillou. with a broader leaf. The history of the tree was recorded in 1916 by Cramer (1916c, p. 402). A planting of seedlings of this tree showed the great variation which is the rule with seedlings of coffee hybrids, but in this case growth was very good and yield fair. A mother tree chosen from this planting of Robusta Bgn.124.01 gave vigorous seedlings, and seed of this clone were later used on a large scale for raising stocks for grafting, since the root system they had, showed increased resistance to nematodes, and since most clones, even those of very different origin such as Liberica

x Arabica hybrids, did very well on them (Cramer, 1928, p. 47). There has been a suspicion that one of the other strains often used as a stock for grafting, Robusta SA.109, was of a similar hybrid, with Quillou blood. The tree made a somewhat Quillou-like impression and showed rapid growth (Hille Ris Lambers, 1931a, p. 691).

The older plantings of the species C. ugandae at Bangelan were not pure but consisted of its offspring crossed with other robustoid species. Generally speaking, these hybrids were resistant to adverse conditions such as drought and heavy shade, but under favorable conditions they would not reach such high top production as Robusta (Cramer, 1916c, p. 400). From these plantings mother trees were selected, and thus the Ugandae mother trees from Bangelan are probably hybrids of other robustoid species with C. ugandae and belong to the class of "hybrids within the group". Some of these presumed hybrids give good producing seedling strains which are considered to have practical value. Ferwerda (1935, p. 10-11) mentions Uganda Bgn.2.01 and Bgn.2.08 as such. In both cases the mother trees were Robusta-like. In recent years artificial crosses were made between robustoid species with the objective of getting good, vigorous stocks for grafting, for instance, Robusta SA.13 x SA.109; BP.4 x SA.109; and Quillou Bgn.66 x BP.4 (s'Jacob & Hille Ris Lambers, 1938, p. 39).

In Peradeniya in Ceylon, various strains of robustoid coffee were tested. Besides Quillou coffee a hybrid, probably of C. canephora with another robustoid kind, gave the highest yields. This hybrid was introduced in 1903 from M. Leboeuf of Paris, and the bushes consistently bore heavier crops than any others of the Robusta type (Anon., 1931b, p. 197).

FURTHER DEVELOPMENT

When the list of hybrids used in commercial planting in Indonesia is reviewed, it is discovered that they were all originally spontaneous hybrids found by chance on estates. This situation may change, however, since in recent years the research institutes of Indonesia have taken up hybridization on a large scale and have obtained some very promising types by artificial crossing, especially hybrids with much larger beans than the ordinary or the improved Robusta strains, surpassing even Arabica in size of the bean. These are hybrids not only between different kinds in the same group, but also between different types of the same species. A surprising progress has been obtained by the mutual crossing of large beaned mother trees.

The crossing of BP.42 with SA.94, both large beaned, gave a number of new clones with beans of a weight not yet reached with Robusta. For instance, SA.814 was found to have an average bean weight of 0.40 gr. against 0.20 gr. for SA.13 and 0.28 gr. for BP.42, up to now one of the largest beaned forms (Hille Ris Lambers, 1941, p. 1531). In other cases Congustas have been crossed with certain robustoid species. Hille Ris Lambers mentioned the hybrids of BP.42, pollinated with Kapakata, which inherited from the mother tree the larger number of berries per node, the larger berry, and the larger leaf, while the pollen parent transmitted its dense branching habit to the hybrid. He also cited Schweiser's work on Arabica-Robusta hybrids and the new material introduced in 1938 from Africa. More details about recent work in hybridizing were collected by s'Jacob & Hille Ris Lambers (1938, p. 38).

Crosses between the species of the same group have already been mentioned as providing better clonal seed for the planting industry by replacing the monoclonal seed with seed representing special combinations. Crosses could also produce new mother trees which combined the desired characteristics of each of the parents. These new mother trees were tested at once, both for the production of seedlings of higher value and for development into clones. With intra-group hybrids the uniformity of the F₁ generation was high. This work has been done with the robustoid group and with Arabica and its close kin.

Hybridizing on a large scale may be carried out in three ways: (1) In biclonal seed producing fields, although there is this objection that when the combination of two particular clones is no longer desired, the only way to save the field for further seed production is to graft over the stocks of the less desirable parent. (2) In monoclonal plantings fecundated by artificial pollination with a desired clone. (3) In large monoclonal plantings with 4 other clones for pollination at the four corners, a system which produces four different combinations, while the unmixed monoclonal center can still be used for artificial pollination.

In addition to the intra-group hybrids, trials have been made with several combinations of different species. Along with Arabica-Robusta hybrids, crosses of C. arabica and C. congesta were made with the objective of improving the quality by the C. arabica blood. Preliminary results were promising. Another series was that of Congusta x Robusta, which it was hoped might combine the great self-fertility of C. congesta with C. robusta characteristics and thus be suitable for estates in higher altitudes with a moist climate. The presumed hybrid SA.36, crossed with BP.42, gave good results, and many new mother trees were chosen from the first generation of individuals. But in the dry climate of the Kaliwining Station this hybrid was disappointing. From such preliminary data it

may be concluded that at present hybridization has a place in the development of the coffee industry which is justified by the results obtained in commercial plantings with the old spontaneous hybrids.

CHAPTER 28
THE MARKET PRODUCT

STORING THE MARKET PRODUCT

When the preparation of the coffee is entirely finished in Indonesia, the product is put into bags holding one picul each (61.76 kg.) to wait for shipment to the local buyer market or to the port of exportation for sale on the world market. The storing of the market product was found to require some precautions well known to the planter in Indonesia. The bags should never be put directly on a concrete floor, but should be kept above the floor on dunnage to allow air to circulate under them and to prevent moisture from the concrete being absorbed by the coffee. It was also a general policy, when the various grades had been bagged, to mix the contents of all the bags of each grade once more, keeping the grades separate before sending the product to market or to the buyer. There may be an empirical basis for this in what has been found out about the taste of coffee from individual clones.

Stored coffee was known to have several enemies, particularly insects and moisture. As long as the moisture content of the air could be kept under a limit between 65 and 75 per cent, there was no danger. If kept at this point, the color changed, the beans became paler, and the odor changed into that characteristic of stored coffee. If the air contained more than 75 per cent moisture, the odor and taste became musty. In a normal storehouse, the moisture was about 75 to 80 per cent, but if the floor was raised above the soil and the roof made of galvanized iron, the rise in temperature during the day kept the relative moisture at 73 to 75 per cent. If it could not be kept this dry, special measures had to be taken such as storing the coffee in bags with dedek, the broken parchment skin coming from the huller. Another method consisted of applying an after-drying at a low temperature and then protecting the product with the odorless and waterproof sisalkraft treated paper. It was put around the coffee and glued together with asphalt of a low melting point, and 28 sq. m. of paper were required for 50 q. of coffee. The cost some years ago was 14 cts. per q. Another way was to store coffee in a shed which could be heated slightly during the night and on rainy days (Roelofsen, 1939a, p. 1303). During the World War 1914-1918, a small estate stored its product in soldered tins, but this method was of course, rather expensive.

In the days when Arabica predominated, aged coffee ("legkoffie") had a good reputation and fetched high prices. A description of the way the "legkoffie" was prepared was given by Kramers (1904, p. 66). In the large sheds in Pedang, Batavia, and Makassar, the market coffee was kept in heaps until it had assumed the desired brown color when there was a demand for it. During storage a chemical change was found to take place in the beans. Some components were oxidized, and the taste became milder, through the action of an enzyme which needed the presence of a certain amount of moisture. Coffee kept dry did not change. To become "aged" it had to absorb a certain amount of moisture. In Makassar, many years ago the market coffee was spread on racks, and earthenware pots filled with water were placed between the racks to keep the air moist during the dry season.

The aged Arabica was often attacked by a small weevil, *Araecerus* sp., which deposited its eggs in the beans. The larvae lived in them, and the newly formed beetles bored holes through the bean for emergence. According to merchants the loss in weight through the insect was only 2 per cent after two years, but this estimate was probably too low. The damage to the beans did not reduce their value. On the contrary, it was a proof of their aged condition. There was a difficulty, however, in that since 1933 coffee imported into the United States may show no more than 10 per cent "coffee with holes" (Kalshoven, 1938, p. 99).

COFFEE ON THE MARKET

A table of 21 pages in Ukers (1935), book entitled All About Coffee (p. 212-232), giving the names of the principal kinds of coffee grown in the world includes a description of the various kinds of Arabicas, Robustas, and others from Indonesia. Several of these Arabicas from Sumatra were conceded to be the finest the world produces. "The green beans are large, uniform, and vary in color from pale straw to deep mahogany, according to the ageing. They have a smooth, heavy body, the fancies possessing an almost syrupy richness". (Ukers, 1935, p. 226). The Robusta from Sumatra districts of Palembang, Bencoolen, etc., and Java was described as having a "small, yellowish-green, round bean; quality approximately that of middling Arabian, ranking a little under good average Santos. Natural, poor roast. Washed, good roast. Thin cup. Used as filler". (p. 227).

In the old days, when Indonesia still produced only Arabica -- the long famous "blue Java coffee" -- the product had an excellent reputation and often fetched very high prices. The description of various commercial kinds of coffee and the classification of Java coffee in Anon. (1903, p. 55) is of historical interest. It was well known that Arabica produced at a high altitude, had a finer flavor than that from plantings in a lower situation neared to sea level. Even now the Arabica

from high altitudes in Sumatra is highly appreciated.

In a description of the main commercial kinds of coffee Ukers (1934, p. 26) noted, "The finest coffees in the world come from the Mendeling and Ankola districts". However, Arabica from estates at high altitudes in Java fetched the best of prices. The characteristic of the Ankola coffee are described thus: It has a heavy body and delicate, rich, musty flavor (Ukers, 1934, p. 50).

Liberica also has its merits. Characteristics of this kind of coffee are its great strength and "body". The taste is pleasant, and Java Liberica gives a better beverage than the Africa. It was especially recommended for blending with light Rio or Santos or any other coffee which lacked strength and body (Anon., 1901a, p. 29). Before the coffee market crisis of 1897 Liberica brought a good price, and often the market price was slightly higher than the price for the Java Arabica. In 1891 the standard quality of Arabica "Java good ordinaire" brought 54-54½¢ in Amsterdam, with Liberica 56¢ (Soekaboemische, 1891, p. 10). This situation changed in 1897. In the course of that year the prices dropped suddenly. The average prices paid for the coffee from the government plantings, for instance, were 50½, 51, 55½, 38¢; in 1898, 34, 35¢; in 1899, 25½¢; and in the period 1900-1909 they fluctuated between 30 and 38¢ with an occasional drop to a still lower level. From 1909 on Robusta appeared on the list of kinds of coffees exported from Indonesia, and soon it won the leading position from there.

The difference in appearance of the market coffee is easily conspicuous enough to prevent the mixing of Robusta and Arabica. Arabica has long been known to have a longer, flatter bean, with a more open groove and a very flat underside with a rather sharp edge, while in Robusta this is rounded off (Huitema, 1935, p. 209).

Robusta was handled more as bulk product, unlike Java and Liberica coffees, which were fancy articles (Cramer, 1918, p. 419). The quality of Robusta was always considered lower than that of the old "Java coffee", or Arabica. The latter was sold under the name of the estate which had produced it. Robusta being a bulk article, its source was left to the seller as long as the product answered the demand that it be "of fair average quality" for the cropping year (Stibbe, 1923, p. 1014). Thus the Soerabaja F. A. Q. contract stipulated that the product should consist of fair, regular beans, free of "stink coffee", with a maximum of 0.5 per cent of black, broken and/or burnt beans; should be of a clean preparation, and with a maximum of 2 per cent of borer damaged beans. The "telquel" contract allowed no more than 5 per cent of "boeboekcoffee", or borer damaged beans, in the market product. It may be true that the days of the fancy article, sold under the name of the estate and on the merits of the product known from such an estate, are past. Still, even much later entire crops of certain estates were often sold to exporters, and the reputation of the estate played a role in the evaluation of the product, since some estates delivered "telquel" coffee with much less than the allowed maximum of borer damaged beans (le Conge, 1934, p. 658).

Other pests, besides the berry borer, can damage the market product in a more indirect way. For example, in the 1938 report of the Besuki Research Institute was compared samples of the market product of Arabica from trees heavily attacked by the scale *Pseudococcus citri* Risso, and from trees free from the pest. The former showed a much higher content of malformed beans. After storage for one year, the taste of the "scale coffee" was only "fair" while the taste of the coffee from healthy trees was considered "good" (see Kalshoven, 1938, p. 71).

In the earlier days of Robusta, the curing was sometimes not done properly, and the product was offered on the market with the silverskin still on it. Such coffee brought much lower prices than the well-cured quality (figures by Cramer, cited by Wester, 1916, p. 127). Later all estate coffee was well up to the standard quality.

In the early Indonesia market, coffee was brought there by exporters, who sent it on to the world markets where the best prices could be obtained. The exporters possessed a good knowledge of the requirements of the various markets including the nearby smaller ones, the markets in Holland, France, and other European countries, and as years went on the principal market for coffee in New York. The exporter often judged the coffee on its intrinsic value and on its appearance. The first criterion was the less important.

In more recent times practically all estates prepared their coffee well enough so that taste and flavor were neutral. Bad flavor, acid taste, and "stink coffee" have practically disappeared. The roasters in Holland paid more attention to the taste, but the total quantity of the Java crop consumed in Holland was only 6 to 10 per cent (le Conge, 1934, p. 654). A good deal of attention was given to the size of the beans. This size depended on many factors not under the control of the planter. It has already been noted that estates in the lower belt produced smaller beans than those in the middle belt. Weather conditions during the ripening, and the size of the crop may also have some influence. However, the planter could control somewhat, the size of the product offered for sale by careful grading. It was held that the smallest beans, the so-called "kried boon" under 5 or

5.25 mm., should be discarded, and expert advice also recommended the removal of even the "small beans", under 6 to 6.25 mm.

The small and very small beans present a difficulty to the roaster. The smaller the bean is, the quicker it gets entirely roasted. Very small beans "gas" quickly, and this means a loss of weight so that their presence causes a reduction in the output of roasted coffee. Therefore the roaster needed to have beans of a uniform size (le Conge, 1934, p. 654). Roasting always means a loss in weight through the escape of the volatile products under the action of the heat.

Estates commonly sold their entire crop at a certain price before delivery, generally as "tel-quel", but, as has been stated, the content of borer damaged beans was often under the permissible 5 per cent. In this connection le Conge remarked that heavily damaged beans were sometimes present and that this should not be the case, since such beans could easily be found and discarded during the picking. He observed that the trade preferred a product with 3 per cent slightly damaged beans to one with 1 per cent heavily damaged beans. This is understandable because the percentage figures are taken by weight, not by number of beans, and the heavily damaged beans are, of course, lighter than the ones which are nearly sound. De Ligt (1935, p. 1260) also recommended the discarding of all heavily borer damaged beans. In addition all beans which were black could better go into an inferior grade, and the contract coffee should contain only "top damaged" beans.

The color of the beans has long had some importance in the market somewhat as follows. A bright green color appears to have been preferred for Robusta. Such coffee could be sold in every market, and this was not always the case with other colors. On the other hand, yellow and lemon yellow coffees and especially beans which had a speckled appearance were difficult to sell. The various markets demanded different colors. Ceylon preferred a greenish color. In Europe a yellowish Robusta was appreciated more than that of other colors. Details on the ways in which the various kinds of coffee were judged in the market by experts was given by van Oss (1927, p. 1059).

The prices on the local market in Indonesian centers, have depended primarily on the quotations on Rio N° 7 in New York, the largest coffee market of the world. The nominal price for Java robusta W.I.B. was about this New York quotation, with something added. The Bureau for Export Business of the Office for Commerce made a comparison of prices of Robusta W.I.B. and Santos Superior and found that there was a close correlation between the two. Interesting graphs and descriptions of market conditions for 1929-1938 showed this correlation (see Anonymous, 1939b, p. 126). The annual quotations of the Amsterdam market on Java coffee for 1887 to 1915 and on Robusta for 1919, to 1936 together with those for Good Average Santos, or "loco Santos", were given in Wichers Hoeth (1937, p. 189). The lowest quotation for loco F.A.Q. was 12.5¢ per $\frac{1}{2}$ kg. in 1935, the highest 68¢ on 25 August 1919, and 62¢ on 31 December 1924 and 30 June 1925. Another high level was reached in 1928-29, but after that the price declined steadily to the level of 12.5¢ just cited. Further interesting historical data on the coffee trade on the Amsterdam market during World War I are in Wichers Hoeth's Gedenkboek (1937, p. 99).

The coffee quotation in Amsterdam gives an idea of the proportions of the value of the various kinds from Indonesia. In 1938 the market opened in January with 16¢ for Superior Santos and 13¢ per $\frac{1}{2}$ kg. for Robusta F.A.Q. The prices varied little in 1938. In July both kinds were quoted at 13.5¢. Prime Robusta from Mandheling was quoted at 8.25¢ in July. The market for Arabica went up in the second half of the year. Coffee from Timor received from 20 to 27¢ Sumatra Arabica increased from 21 to 27 or 28¢, and the "washed blue Java" from estates, sold for from 25 or 26¢ to 33 or 34¢. Liberian coffee from Surinam was 10 $\frac{1}{2}$ to 11¢ per $\frac{1}{2}$ kg. during the first half of the year and 14 $\frac{1}{2}$ ¢ in September.

Knaus (1936, p. 925) the specialist on the improvement of the curing process at the Malang Research Institute, was responsible for a good deal of progress in this aspect of the production of the raw material. He often insisted on the importance of standardisation of Java Robusta.

The Java Robusta is practically always used for blending, and this blending is done when the beans are still green. The native produced Robusta is preferred by many because it is prepared by G.B., dry curing, and is therefore more reliable with respect to taste.

THE TRADE IN NATIVE COFFEE

The native market product of Robusta in Indonesia is poorer in quality than that from estates. It is the cheapest quality of coffee on the market, and most of it is prepared by the dry cure. In many regions where the beans are hulled by hand pounding, the ripe berries are first crushed and then dried. The further treatments can be carried out at various stages in the trade. Some centers put out considerable quantities of coffee, uniform in appearance and in a satisfactory state with respect to the drying on the market.

Sometimes the product is brought from the natives in the berry, and the market coffee is pre-

pared from it by the W.I.B., or wet, cure. As far as is known, this has never been a success. The buyer receives a less homogenous crop than he would have received from an estate, and the difference in price between the raw product and the dry cured product is smaller than it seems because the former has a higher moisture content. The percentage of borer damaged beans is larger, and it is difficult to get enough of the product at a reasonable price to run the factory at full capacity.

The normal scheme for the trade in the past has been to have first a small buyer, then an intermediate buyer, then the exporter. Most of the product went to America, to northwestern Europe, to the Mediterranean, and then to Eastern markets. The export of coffee with more than 2 per cent components other than coffee and more than 8 per cent borer damaged and black beans, is prohibited by law. Furthermore, the coffee may not lose more than 3 per cent of its weight by exposure for one hour in the sun. One author (Roos, 1937) criticized these regulations. He argued that the 2 per cent foreign components could be cut in half, since in practice the percentage was often even lower, and that the 8 per cent borer damaged beans was too severe, especially since the picking of inferior components and broken beans could still be used for making a fair roasted coffee for "coffee tubruk", that is coffee made in the native way, leaving the ground coffee in the beverage. It is necessary for the market coffee to reach the foreign market in a clean condition, not moulded, and this would be the case if the moisture content was under 15 of 15.5 per cent. In contrast in those days, the native Arabian coffee was a fancy article. There were real differences between the various grades (Roos, 1937, p. 503). It may be added that since the criticisms by Roos were published the situation has been altered.

Experiments have been made with various methods of curing native Arabica and with berries in various stages of maturity. The results showed that the usual native method of dry cure, drying in the berry and then pounding, or pulping and drying immediately afterwards, gave the best results. If the berries were harvested when still unripe, a poor quality was obtained with many black and off color beans. Black and dark brown beans which were sometimes found in stored coffee, "legkoffie", is said to be caused by harvesting unripe berries or by faults in the curing (Huitema, 1935, p. 209).

GOVERNMENT HELP TO PRODUCERS

At one time the critical state of the coffee planting industry forced the government to come to the aid of the producer. In Holland a temporary tax was levied on the imports of coffee from foreign countries. The revenue from this tax amounted to about 600,000 guilders per annum. The government added 200,000 and the 800,000 guilders were turned over to a special agency established to improve the quality of the market product, especially that of the native producer. In August 1940 this "Coffee Fund" was extended to include a Commercial Division for applying a single buyer and single seller policy. This division bought all coffee produced in Indonesia except Arabica, at a fixed price with the promise that an ultimate loss on the sale of this coffee would be absorbed by the fund to a maximum of 3,000,000 guilders. The price for export quality estate coffee was fixed at 13 guilders per q. in 1940, and at 17 guilders in 1941. The liquidation of the stocks left a considerable profit which was distributed among the producers, so this policy proved to be entirely successful.

The Coffee Fund established the following standard qualities for the native coffee:

(a) Native Robusta with 3 per cent triage, of sound quality, without musty or slightly mouldy beans, maximum 8 per cent weevil, free from black and dry berries, free from skins and foreign matter, maximum of 14.5 per cent moisture according to the method of Brown-Duval. The coffee was to contain not more than 2 per cent beans which can pass through a wire sieve with 4 mm. mesh.

(b) Native Robusta with 8 per cent triage, a quality covered by the same description as the first, except that instead of "free black berries" it was described as "practically no black berries"

(c) Native Robusta with 15 per cent triage, of sound quality, without musty or slightly mouldy beans, maximum of 1 per cent dry berries and skins, some slight impurities allowed if these, together with the dry berries and skins, did not exceed one per cent, with a weevil percentage as usual for this kind of coffee, and a maximum of 14.5 per cent moisture according to the method of Brown-Duval. It was not permissible for the coffee contain more than 2 per cent beans which could pass through a wire sieve with a 4 mm. mesh.

(d) Native coffee with 30 per cent triage, a quality covered by the same description as immediately above, but without the last provision on the 4 mm. mesh sieve.

(e) Native coffee with 50 per cent triage, or the same size as that just described.

CAFFEINE CONTENT

Several attempts have been made to connect the taste and flavor of coffee with some chemical property, for instance, with the caffeine content of the beans, but no relation has been found. Details on the chemistry of the coffee bean were published by Gorter (1907, p. 1).

Duarte (1930, pp. 1-10) reported the following caffeine contents of coffees from San Tomé:

| <u>Coffee species</u> | <u>maximum</u> | <u>minimum</u> | <u>average</u> |
|-----------------------|----------------|----------------|----------------|
| <u>C. liberica</u> | 1.06 | 1.0 | 1.20 |
| <u>C. arabica</u> | 1.23 | 0.70 | 1.01 |

According to McClelland (1924, p. 6), Arabica grown in Puerto Rico was comparatively low in caffeine. It contained, on dry bases, 1.12 per cent.

A species with caffeine-free seed, Coffea humblotiana (see Anon., 1902, p. 211), is mentioned in the journal Teysmannia. The absence of caffeine in this species was curious, since otherwise it resembled Arabica closely (Bertrand, 1905, p. 209). According to Chevalier (1937a, p. 822) this species may have possibly disappeared since the opening of the jungle. A caffeine-free coffee from Madagascar received under the name of "Mautsaka-coffee" was studied by Bruijning (1915, p. 114). The botanical aspects could not be determined. The seed were free from caffeine. When roasted they had a good color and smell, but the beverage made from them had a bitter, lasting taste. The presence of a bitter substance called cafamarine in the caffeine-free seed of C. humblotiana was described by Bertrand (1902, p. 211). His article lists the caffeine-content of twenty-four samples of coffee, primarily Arabica, from various countries. C. mauritiana is recorded as containing a very low content of 0.07 per cent, and C. humblotiana as having none at all. For most of the other kinds the figure is over 1 per cent. For C. canephora from the French Congo it was 1.97 per cent. The caffeine content of the samples of Arabica apparently varied between 0.86 and 1.60, averaging 1.08 per cent.

Chevalier (1938, p. 826) stated that none of the 26 species of coffee known from Madagascar and neighboring islands, and tested for caffeine contained it in the seed, except perhaps C. lancifolia, which had not yet been analyzed. So far none of the caffeine-free species has been of commercial importance. It appears that the merits of the caffeine-free kinds of coffee have been viewed with too much optimism (Anon., 1901b, p. 67), since they usually gave a product with an unpleasant taste.

The caffeine content of Arabica from Java, with percentage figures of 1.48, 1.58, and 1.64, is relatively high compared with that of market coffees of other origin (Ind. Mercuur, 1892, p. 481). Robusta from Sierra Leone, a mixture of Java and Congo types, was reported to have a caffeine content of 1.3 per cent, while native Robusta from Tanganyika had 2.2 and from Ceylon also had 2.2 per cent (Anon., 1928, p. 419, and p. 421). The beans of C. stenophylla in Buitenzorg were found to contain 1.8 per cent of caffeine (van Romburgh, 1903, p. 369). The C. canephora var. kwilensis was recorded as containing 1.77 per cent (Pieraerts, 1918, p. 165). Gorter found no caffeine at all in C. mauritiana (Jaarboek, 1908, p. 81). As already stated, several of the species occurring wild in Madagascar and neighboring islands did not contain caffeine in their seed. The occurrence of caffeine-free kinds of Coffea was denied at first by J. Pritsker and R. Jungkuns, but they later had an opportunity to analyze material from C. dubardi and C. pierrei, both from Madagascar, and found that these did have caffeine-free seed (see Anonymous, 1938a).

Some percentage figures for the caffeine content show that the percentage is not higher with coffee famous for their good flavor such as the old java coffee, and percentages may vary a good deal with coffees which are similar in taste. Great differences were found even between different Robusta trees.

The caffeine content of the seed of several of the species grown in Indonesia were studied by Gorter (Teysmannia, 1908, p. 776), and he found the following percentages:

| | |
|--|------|
| <u>C. arabica</u> | 1.34 |
| <u>C. arabica</u> var. <u>maragogipe</u> | 1.10 |
| <u>C. arabica</u> var. <u>mokka</u> (small bean) | 1.11 |
| <u>C. liberica</u> | 1.52 |
| <u>C. abeokutae</u> | 1.45 |
| <u>C. robusta</u> Egn. no. 54 | 2.07 |
| <u>C. robusta</u> Egn. no. 65 | 2.40 |
| <u>C. quillou</u> Egn. no. 70 | 2.79 |
| <u>C. quillou</u> Egn. no. 59 | 2.57 |
| <u>C. quillou</u> Egn. no. 86 | 2.39 |
| <u>C. canephora</u> no. 15 | 2.00 |
| <u>C. canephora</u> no. 20 | 2.20 |

Figures previously published by Gorter (Jaarboek, 1906, p. 34) were:

| | |
|-------------------|-----|
| <u>C. arabica</u> | 1.6 |
|-------------------|-----|

C. liberica

From an extensive comparison in Indonesia of 80 samples of Robusta market coffee, Knaus (1930, p. 26) found that the caffeine content varied between 1.97 and 2.60 per cent, with an average of 2.29. No typical figures for the different regions were found. The varieties or forms composing the plantation seemed to have no influence. Quillou numbers from Bangelan had from 2.90 to 3.05. One Robusta clone, R.105.03, had a high percentage of 2.96, as did two clones of Congensis: 161 with 3.00, and SA.109 with 3.25 per cent.

The percentages of caffeine content of other species were as follows:

| | |
|-----------------------------------|------|
| <u>C. arabica</u> (Idjen plateau) | 1.47 |
| <u>C. liberica</u> (Surinam) | 1.53 |
| <u>C. excelsa</u> (Lamp. Distr.) | 1.21 |

A caffeine content of 1.89 per cent was found in the seed from wild Excelsa trees (Chevalier, 1905, p. 519). Apart from the naturally caffeine-free coffees which have been mentioned, there is a commercial caffeine-free-coffee, consisting of ordinary market coffee submitted to a process by which most of the caffeine has been extracted.

PASTE AND FLAVOR

So far chemical analysis has not succeeded in finding striking differences between kinds of coffee of different value, when judged aside from their flavor (Anstead, 1938, p. 724). The flavor of coffee and the methods of measuring it were studied by Punnett (contribution to Ukers' All about Coffee, 1935, p. 299), who found the standard cup method of flavor measurement the best for testing factors such as the influence of the coffee-making device.

In this connection an instrument which is used to determine the intensity or smell of a substance may be mentioned, although it has not been used for appraising coffee, only for comparing the odor of various samples of cocoa. It is the "osmoscope", invented by Fair and Wells and used especially for determining the limit at which a smell is still perceptible. With this instrument the air to be tested is mixed with varying quantities of odorless air, starting with the largest quantities so that the point at which the smell is still perceived can be noted. Another method was devised by Giesberger, who described his as the "olfactometric method". A number of bottles are partly filled with the substance for which the limit of smelling is to be determined, diluted in increasing quantities of odorless water. The bottles are allowed to stand for an hour so that the odor can spread to the air of the upper (empty) part of them. The bottles are then tested by smelling this air through a tube, starting with the bottle containing the most diluted substance. In this way the limit at which the smell is still perceived can be determined fairly accurately (Giesberger, 1937, p. 170).

In his thorough study of the factors influencing the quality of market coffee, Roelofsen (1939c, p. 177) made an attempt to find chemical criteria to determine the quality of the aroma and taste. He experimented with roasting coffees of different quality to study the effect. He found that the quality of the aroma could be judged only with the beverage in the cup. The experiment was made as objective as possible by handling it blind, and by repeated judging.

It is clear that under such conditions the judgment of experts on the quality of coffee is always of a somewhat subjective character. Nevertheless, it gives useful indications of the merits of certain trees or clones. In the years when new kinds of coffee were introduced the opinion of experts was asked. For example, Abeokuta coffee was recommended for experiments after brokers had expressed a favorable opinion of it (Cramer, 1913, p. 415). In 1917 a verdict was obtained from an expert in Amsterdam on samples of Quillou, Robusta, Canephora, and Ugandae. All these various kinds were considered to possess about the same taste (Anon., 1917, p. XI). When the Research Institute for Central Java started Robusta selection, the uniformity of the product of every tree was very striking. When this product was submitted through the Netherlands Trading Company to brokers, they reported that the product of some trees was of superior quality. For example, the beans of tree no. 1 were particularly praised, and the report says, "Such a product would cause a complete reversal in the valuation of Robusta coffee". In the report it was described as "very large beaned, noble, very well cured"; the roast as "very large W.I.B."; the taste as "pure"; and the price estimated at 35¢. For other samples, this estimate varied between 26.75¢ and 30¢, the latter price for another large beaned type (Voute & van Hall, 1914, p. 11).

In practically all selection, attention has been paid to the size of the bean, a characteristic which had been found to be hereditary (Gandrup, 1935, p. 926). Plants from first generation progenies, with berries surpassing in size those of both parents, have been obtained from Robusta crosses. One seedling with parent nos. BP.42 x SA.94, had beans weighing 0.40 g., a great advance compared with the already large sized bean of BP.42, which averaged 0.28 g. (Hille Ris Lambers, 1941, p. 1530, with photograph).

An attempt has also been made to test the taste of the market product from various clones in Java and elsewhere in Indonesia. Chemical investigations of Arabica and Robusta hybrids by the Besuki Institute, showed that the caffeine content was also a hereditary factor. Hybrids showed all transitions, from a high to a low content, corresponding to that of the parents. Furthermore, a positive correlation was found between the fat content of the bean and the quality. According to Schweiser (1925, p. 1429) the fat content was highest in Arabica and lowest in Robusta. The hybrids were intermediate in this regard. The correlation was confirmed by tasting experiments in Malang and Djember. It was thought possible that the aroma substances originate during the roasting and are then absorbed by the fatty substances.

The Besuki Institute submitted some samples from various BP. mother trees to experts and received a very favorable report on the taste of one type, which was estimated to have 10 per cent higher market value than the other types tested. The Malang Research Institute chose for its test nearly 30 clones from its Soember Asin Station (Roelofsen, 1939, p. 814). The product from each clone was cured separately, and tested by the Institute and by several experts in Holland. The result was striking. Each clone had its own character. One had a special flavor, another was very dull, a third somewhat less pleasant. All these samples were abnormally dull, but the average for the whole estate had a more pleasant taste with a fuller aroma.

German research workers have investigated the components of the coffee aroma. They isolated over 20 substances and made a synthetic coffee aroma from them. Some of the components had a very unpleasant odor, but when used in a very low concentration, in mixtures with the others, they contributed to a pleasant odor. Thus it appeared possible that a clone giving a product with an unpleasant taste all by itself, might participate in giving a good full aroma to a mixture. This principle is applied in blending coffee. As an expert by the name of Aborn, pointed out in 1926, the blender had to follow "the law of contrast". In all blending it is apparently the use of opposites that brings out the rich fragrance of the flavor. Ukers (1935, p. 251) gave suggestions for several blends. Typical low priced coffee blends in the United States are sometimes made up of half washed Robustas and half Colombian Consumos.

ROASTING AND SUBSTITUTES

Very little about roasting has appeared in the literature available in Indonesia. The only books containing information about the process were Ukers' All about Coffee (1935) and Thurber's Coffee from Plantation to Cup. As the latter dates from 1881, it cannot be considered up to date. It contained some details about blending and gave figures on the loss in weight by roasting. This varied from slightly over 17 per cent for Java grades to slightly under 12 for Rio coffee. The difference was explained by the fact that the Rio bean was more solid than the "spongy" Java Arabica, coffee bean (Thurber, 1881, p. 28). Thurber added to his recipes for blending a picture of a coffee roasting plant of his day, consisting of a series of more than a dozen large roasting cylinders (p. 26).

Ukers (1935) described the coffee roasting equipment in various parts of the world with good illustrations of the machinery used. In the United States were those that had machinery for roasting at least 2 bags of green coffee, 120 kg., at a time. Plants treating from 50 to 150 bags per day were the most common, while in Europe smaller plants were more frequent. Special machinery has been devised for mixing the green coffee and for cleaning it, for instance, for removing the bits of string from bags. The heating was usually with gas. After the roasting the beans were cooled. The cooling was then followed by an air suction operation called "stoning", which removed any stones or other hard material that would damage a grinding mill. This "stoning" was considered best done after roasting, because coffee beans then were not only lighter but a good deal more bulky (p. 273). Often the equipment included additional machinery for grinding. The most modern equipment gradually reduced the bean to finished size, using a multiple arrangement of steel rolls, and it reduced the chaff to powder without separating it from the ground coffee. This method permitted the grinding operation to be carried on in an enclosed machine. Hence the carbon dioxide gas, given off by the coffee itself, protected the flavor oils from oxidation (p. 248).

A detailed description of the roasting process was given in Kaffee (Ciupka, 1937, p. 56). The beans were found to swell in the roasting process to such an extent that a single kg. of roasted beans occupied a volume of about 100 per cent more than a similar quantity of raw beans. The loss in weight by roasting depended on the kind of the coffee and the manner in which the roasting was done. Generally it was about 16 or 17 per cent. Hints on blending were added.

Burkill (1935, p. 625) gave a good summary of the effects of roasting. The most obvious change was production of a fragrance, attributed to a mixture of several substances. It was partly due to the volatile oil called caffeol, which was produced at the expense of other substances, and partly to the sugars which were caramelized. In a good processing plant, the rapid cooling which followed

roasting was intended to prevent undue loss of the volatile caffeine. At the same time there were losses of water, fats, and caffeotannic acid; and the cellulose cell walls became brittle and brown. As the temperature of roasting was above the at which caffeine sublimes, some of it was also lost. The chemistry of the process of roasting remains obscure, but it has been said that the aroma of the caffeine is obtained if caffeine, sucrose, and caffeotannic acid are heated together. Others say that the aroma is produced by heating the latter two substances together. Burkhill (loc. cit., p. 626) remarks that if these statements are correct, coffee tree selection should be based on the amount of caffeotannic acid present in the bean.

Roelofsen (loc. cit., p. 183) found that 100 g. of Java Robusta gave about 84 g. of roasted coffee. The volume swelled from 100 to 160, figures which were influenced by the moisture content of the beans. Roasting made the bean lose moisture and decomposed the fiber. The sugar was caramelized and disappeared for the most part, increasing the caffeine content, which averaged 1.21 per cent in roasted coffee. Part of it was volatilized by the high temperature (Utermark, 1925, p. 179).

Roasting experiments at 200° C. (Roelofsen, 1939c, p. 182), showed that a mixture of moist and dry green coffee did not give an uneven roast. A mixture of full and broken beans or of blueish and yellowish beans also gave an even roast. The so-called "witboon" beans which, during the pulping or washing, were divested of the parchment skin, have a smooth, glossy surface, in green as well as roasted beans. The substances which gave the typical coffee aroma during the roasting were soluble in water and alcohol but not in chloroform or petrol ether (p. 193). A concentrated extract of market coffee in water was heated at 230° C., and after it had given off blue vapors, it was extracted with hot water. The extract resembled coffee in taste (p. 185).

Roasted coffee, when stored, loses flavor. This has been attributed to the action of the oxygen in the air on the fat in the coffee. To counteract this, ground coffee has been packed in vacuum tins. However, the vacuum soon disappears because carbon monoxides and carbon dioxide gasses are released by the ground coffee. Bengis investigated the subject (1936, p. 290). The fat prepared from stored coffee was clearly inferior in flavor and taste to that from freshly roasted coffee. In vacuum packed coffee there was a deterioration of the aroma after a month, and after 12 months it was decidedly bad.

Sometimes complaints were received from the United States about the "dull roast" of Java Robusta. It may be that a too narrow setting of the huller caused some of the dust, originating from the silverskin, to be rubbed into the surface of the bean. Samples received in Java were examined microscopically by the Malang Institute and showed particles of dust adhering to the beans in their wrinkles. It was found that this dust could be removed with a brush (Knaus, 1935, p. 744).

It might be added here that part of the coffee produced in Java goes to local roasting plants which use modern equipment and deliver coffee to the public as roasted beans or ground coffee in tins. There used to be a small export of roasted coffee, mainly from Semarang. In 1929 the total export of this from Java was 430 tons, including 326 from Semarang. Since then the export of roasted coffee has declined. It amounted to a total of only 28 tons in 1934. On the other hand, there was an import of substitutes, mainly chicory. In 1939 the imports of chicory amounted to 528 tons, but they since declined and in 1934, amounted to only 3. Other substitutes such as roasted corn have been added to coffee (Scheltens, 1935, p. 1371). In this connection it may be mentioned that an attempt has been made to make the use of substitutes difficult. The "Verpakkings-verordening-koffie" (Ordinance on Coffee Packing, 1940) published in the Staatsblad 1940, no. 535, stipulated that any substance called "coffee" or "roast coffee" on the label might contain not more than 3 per cent of other substances (Anonymous, 1940a, p. 1553).

The use of substitutes in Indonesia has been very general (Bergcultures, 1937, p. 299), especially among Chinese roasters and the smaller Chinese grinders. Even a so-called "coffee" is sold consisting of 90 per cent roasted corn and 10 per cent chicory. Roasted boiled rice and roasted seed of various trees are also used, and the dried skin of the berry, may be mixed with the material to be roasted. The price for these substitutes is f 0.90-2.00 for a tin containing 15, 18, or 20 katti, about 9.3-12.4 kg. Roasted corn is used to such an extent that there are special corn roasting plants which sell their product to grinders for about 4¢ for one katti, or 0.6176 kg.

It is calculated that a cup of coffee with sugar can be served in the native warung for a half a cent and leave a profit. Thus real coffee can be used even by the poorer classes.

When the "Ordinance on Coffee Packing" just cited was prepared, the Chemical Laboratory in Bogor issued a statement (Koolhaas, 1938) calling attention to the high alkali content of the ash of coffee. The alkalinity was found to be 60 to 70, expressed in cm³ normal NaOH solution per 100 g. of dry matter of the roasted coffee, while for the products often used for adulteration, maize and rice, this figure was about 10 and 1 respectively. The alkalinity of the ash was independent of total ash content, which was 3.9 to 6.0 per cent, while the alkalinity of the ash varied between 60.7 and 68.6. Roasted coffee with an alkalinity under 57 had to be considered as adulterated (Kool-

haas, 1938, p. 1).

Roelofsen (1939b, p. 283) developed another method for tracing adulteration of ground roasted coffee. It was known that grains of corn or rice were often used as substitutes. When roasted like coffee, they could still be identified by microscopic examination, and this could also be done with seed of katjang or beans. Skins of coffee berries were seldom used as a substitute. Leucaena glauca has been mentioned as a suitable substitute, and it was tried with pleasant results (Brill, 1916, p. 224). Even livers of oxen and horses were baked and ground into a powder which was used as an adulterant. In the old days the horse liver coffee was the higher priced of the two (Simmonds, 1864, p. 31).

MAKING THE BEVERAGE

The problem of the best method of making coffee from the ground roasted beans was studied by the Department of Biology and Public Health of the Massachusetts Institute of Technology, which published a report by Helen L. Johnson. It was issued under the title "Scientific Coffee Brewing" by the Joint Coffee Trade Publicity Committee. This latter publication is reviewed in the Ind. Mercur, Jg. 48, by Utermark (1925, p. 179). It was determined that the finer the roasted beans were ground, the darker the infusion would be and the stronger the flavor. "Pulverized" coffee and making the infusion by filtration gave the best results. Probably up to 80 per cent of the caffeine dissolved at once in water of 85° C. S. C. Prescott, who conducted the research, came to the following conclusions:

1. The use of very alkaline or very hard water should be avoided.
2. The temperature of the water used for making the extract was of great importance. Boiling water increased the bitter taste. The best temperature was between 85° C., a temperature at which most of the caffeine was dissolved with a minimum loss of the "oil" carrying the aroma.
3. The water should remain in contact with the coffee not longer than two minutes. Otherwise the taste became bitter, and some of the flavor was lost.
4. Coffee which had boiled even for only one minute was noticeably bitter.
5. Coffee which had been in contact with metals took over their taste and became bitter and astringent.
6. Tin, aluminium, brass, nickel, and silver were all noxious to the taste, tin the most so.
7. Glass, earthenware, china, and enamel had no influence on the taste.
8. Some metals were found to form compounds with caffeine, perhaps also with other components of coffee.
9. Differences in taste were partially levelled by the addition of sugar and cream.
10. Finely ground coffee gave a stronger and more aromatic infusion than more coarsely ground beans.

The experiments were made by a number of persons under guarantees that each gave his individual and impartial judgement. Many people preferred coffee made with water of a temperature considerably lower than 100° C. If coffee was prepared with water of under 90° C., the infusion remained clear for a long time and did not lose its flavor, but it had to be kept in a glass or earthenware container. It was important to make the coffee as soon as possible after the grinding.

Similar hints were given by Cheney (1927, p. 822), who recommended that the freshly roasted, finely ground, beans should be treated with water at 95°C. for 2 or 3 minutes. In this manner the infusion removed as much caffeine as could be extracted without a very prolonged treatment.

Ukers (1935, p. 653) included a more recent discussion of coffee making by S. C. Prescott. This worker stated that attention should be paid to the following details: freshness of the roasted coffee, fineness of grind that permits rapid and effective extraction, a method of treatment which conserves the delicate volatile constituents inherent in the freshly roasted bean but avoids the woody and bitter flavors that are invariably found in coffee which has been exposed too long to the solvent action of water on the ground material.

CHAPTER 29
BYPRODUCTS OF COFFEE

SUBSTITUTES FOR MARKET COFFEE

The coffee plant produces some products which may be used as substitutes for real market coffee. The product prepared from coffee beans by extracting the caffeine from them may be considered as such a substitute. The noxious action of coffee can be eliminated by a treatment of the beans before roasting according to Fontoura (cited by Anon., 1934b, p. 1345). When the beans were well washed for a few minutes with water at 65°-70°, a dark oily liquid was obtained which contained the substances first exposed to roasting. The washed beans after roasting made a beverage of pleasant taste and without an unpleasant effect. Caffeine free coffee may be obtained by a similar but more drastic treatment. As stated in a previous chapter, the components of the raw bean which give it taste and flavor are not soluble in chloroform or petrol ether, while caffeine is.

Although the details of the process are secret, some patent descriptions give an idea of the broad lines of the treatment which is applied before roasting the beans. All the caffeine can be extracted from coffee with chloroform if the coffee is finely ground and sufficiently moist. Gorter (1907a, p. 240) stated that the so-called caffeine free coffee of commerce that he studied still contained a small percentage of the alkaloid, viz., 0.2 per cent. A hint on the preparation of the beans for extraction by exposing them in a sieve to a vapor of hot water until they became leathery was mentioned by Gorter (1908, p. 778). In the industrial process the beans were generally prepared by submitting them to some treatment which made the cells more accessible, such as steam under pressure or chemical action. They were then treated with a solvent which was later removed by distillation. The beans were then cleaned. They were said to be odorless and to retain the principles which give the agreeable taste and flavor to roasted coffee. Various processes were used. An improved process which, among other advantages, was claimed to reduce the caffeine content to only 0.012 per cent, was described in the Spice Mill (see Anon., 1930, p. 728). The coffee was first exposed to the action of alcohol steam and then extracted by an odorless solvent, the nature of which was kept secret. The solvent was then extracted with water, which absorbed all the caffeine. Afterwards the water was distilled off, leaving a residue of caffeine which was almost white and 97 to 99 per cent pure. It was further purified, and then offered for sale.

Various methods of making caffeine free coffee are all covered by patents. With the simpler methods the beans were treated with a solvent, and the solvent removed by centrifuging (D.R.P.224.162). Sometimes the beans were exposed during the extraction to a weak electrical current (D.R.P.219.405). Another group of patents covered methods by which the beans were heated to 150° C., then exposed to the action of steam under pressure in the presence of tartaric acid and afterwards dried (D.R.P.-221.116). To this group of patents belong those for making Hag coffee (D.R.P.198.279 and 198.280). Under these patents the coffee was enclosed with dry air at $1\frac{1}{2}$ to 2 atmospheres of pressure. Then acid and/or alkaline vapors were driven through, and it was treated with benzol or other organic solvent. The beans were then freed from the solvent by an alternating treatment with dry air and in vacuo. According to D.R.P.243.530 the beans were first swollen by heating with water or moist air and then extracted with solvents such as benzol, chloroform, etc.

The last group of patents covered the process of soaking the coffee in an acid or alkaline medium. The liquid extracted the caffeine. With D.R.P.124.875, the oldest patent of this type, this was done with ground coffee. Under D.R.P.237.810 the beans were treated with an aqueous solution of ammonia and then with an organic solvent. Under D.R.P.276.014 and 284.374 they were treated with two or more alkaline solutions. Under D.R.P.227.380 the beans were treated with a volatile acid which could be removed by extraction with alcohol or by steam, and finally the beans dried and roasted (Tonn, 1932, p. 123).

The so-called caffeine free coffee prepared by these methods is not absolutely free from caffeine, but such a large part of it has been removed that the coffee has lost practically all its stimulating properties. It may therefore be used by persons who, for reasons of health, have to avoid the use of beverages containing caffeine. The caffeine is separated from the solvent in which it has been dissolved by distillation, and it is then purified. Commercial caffeine is obtained in this way. However, coffee is not the only source of caffeine. It can also be extracted from tea, and the preference for one or the other of these raw products on the part of manufacturers of caffeine seems to depend largely on their market prices.

Other parts of the coffee plant besides the bean have sometimes used for making beverages. The refuse from the curing process, containing black and broken beans, as well as pieces of skin of the berry and of the parchment and silverskin, is sometimes roasted, ground, and mixed with market coffee to make cheaper mixtures.

The dried skins of the berry may be used to make "café a la sultane". The skins, preferably those of empty berries of Arabica which float on the water of the receiving tank at the beginning of the curing process, are used. In the days of extensive Arabica production in Java, these empty berries were sometimes dried separately and sold to local dealers who were said to mix them with Javanese palm sugar and export them to Arabia. Very few references to this byproduct can be found in the literature. In 1897 a demand for coffee skins was reported (Ind. Mercur, 1897, p. 691). Skins of Liberica berries was preferred, and they were said to be used for blending with real coffee. Orders came from the Persian Gulf and Aden. In Persia and Turkey the dried and roasted pulp of the berries is used to prepare a bitter preparation known as sultana coffee (Cheney, 1927, p. 819). A curious old document describing this "coffee a la Sultane", prepared by pounding the dry skins and then roasting them over a fire while they were stirred, was published by van Brugge (1898, p. 460). The chewing of green coffee berries is popular among the native population of central Africa. The green berries are first boiled and, when chewed, have a not unpleasant taste similar to that of rye bread (Hille Ris Lambers, 1939a, p. 1805). This use is not known in Indonesia.

It has been suggested that the pulp of the berry might be used for preparing alcohol. However, Ultee (1908, p. 67), who made a thorough study of the question, came to the conclusion that the low sugar content made it impossible to develop such a process for Arabica and Robusta, or Liberica. Ultee also attempted to discover whether or not caffeine could be extracted with profit from the skins of Arabica berries, the richest kind in this respect. His conclusion was negative, although a content of 0.70-1.00 per cent was found. It is curious to note in this connection that, according to a theory, the first beverage made from the coffee plant was an alcoholic liquor made from the berry (Burkill, 1935, p. 619).

TEA FROM COFFEE LEAVES

In some regions of Indonesia, notably the west coast of Sumatra, and southern Tepanoeli, it has long been a custom among the native population to make a beverage not from roasted coffee beans but from the leaves of the tree. The leaves are strung on little sticks and sold in the native markets as "kopi daon" or leaf coffee. These leaves are toasted and then extracted with hot water in a bamboo sheath (Huiteima, 1935, p. 153). Both Arabica and Robusta are used for this purpose. The leaves were said to be generally taken from suckers, and were not cured with care (Kramers, 1904, p. 62). According to a more recent description (Anonymous, 1926, p. 1), the leaves of Arabica were toasted over a mild fire until they assumed a nice brown color, and then they were broken into small pieces. The consumption of this product is estimated to have a value of some hundred thousand guilders annually. This "Kopi daon" seems to have been made by the native population in Java as well, and there is a regular export of it from certain districts in the neighborhood of Semarang and Japara (Kramers, 1902-1903, p. 503).

The use of dried leaves of Arabica for making an infusion has also been described for Ethiopia (Philippe Paulitschke, 1893, apud Chevalier, 1929, p. 5). In Liberia the native women were reported in 1890, to make a kind of aromatic tea from the toasted leaves of Liberica (Büttikover, 1892).

The use of coffee leaf tea has always attracted public attention. At the International Exhibition of 1851 the leaves were shown (Simmonds, 1864, p. 27). The tea made from Arabica leaves was tried on the London market (Slaney, 1893, p. 613), but it did not meet with a favorable reception and was even said to be undrinkable (Karsen, 1893, p. 628). According to the Planters' Chronicle for 1 January 1931, an article was quoted from an American periodical, the "Grocer and Register", which stated that chemists in Java had been giving all their time to studying a kind of tea manufactured from coffee leaves. However, this was a misunderstanding (Ultee, 1931b, p. 219).

OTHER BYPRODUCTS

In addition to the byproducts just discussed which are allied with market coffee, completely different products are also reported to have been made from coffee. With the enormous overproduction of coffee in Brazil, leading in the past to the destruction of millions of bags per year, it is understandable that serious efforts had been made to use the product as a raw material for some other industrial application. It has been said that the beans were sometimes used as a combustible and as a fertiliser. An entirely different line has been taken up by the H. S. Polin Laboratories in New York, which worked out a method for making plastics from coffee (Anon. Keffie als grondstof, 1940, p. 347). The process was reported to have been developed far enough to be applied on an industrial scale. A large factory was to be built in the state of Sao Paulo, designed to use 1,000,000 bags of coffee per annum and to be managed by the National Coffee Department. The end product would be used for flooring, wall covering, and similar applications. The coffee to be used as raw material was not required to be of standard quality. Inferior grades such as are now destroyed to keep up the market price could also be used.

In 1937 there was a rumor that coffee was being bought in Germany for some chemical-industrial application and that if the experiment should prove to be successful, Germany was prepared to buy 1,000,000 bags. A subsequent note stated that nothing more was known about the matter, and a word of warning against excessive optimism added (see Anonymous, 1937b, p. 1054). Shortly afterwards it was stated that a bag of inferior coffee was known to contain 6 to 8 kg. of oil, 28 to 30 kg. of cellulose, and 600 g. of caffeine (ibid., 1937, p. 1193). The residue from this would still have been useful as artificial fertilizer (p. 1225). In 1939 the making of plastic glass from coffee was again mentioned (Anonymous, Koffie, 1939c, p. 1397) in connection with the work of the Polin Laboratories.

The essential oil from the fragrant flowers has been studied as another byproduct obtainable from the coffee tree. Greshoff (1890, p. 205) collected a small quantity of flowers from under the trees, distilled them with water, and extracted the volatile elements with ether. He obtained a light yellow liquid containing crystals with a delicious perfume, and was optimistic about its possibilities. So far as is known, the production of this essential oil was never attempted on a commercial scale. Probably the output per given quantity of flowers was too small.

CHAPTER 30
INDONESIAN COFFEE IN THE MARKET

WORLD PRODUCTION

After the preceding discussion of the technical aspects of the industry, some data may give an idea of the importance of coffee production in the household of the world and of the place Indonesia occupies among the coffee producing countries. Coffee must be considered one of the main agricultural products of the world in quantity, in value, and in importance to mankind. If it is not indispensable to man's happiness, it certainly contributes a good deal to it. It has been called "the tropics' best gift", and this phrase says more than a long discussion.

The importance of the world production of coffee has been presented in tabular form (Di Fulvio, 1939, p. 441S). This publication showed the total annual production of the principal countries that provided the world with coffee at that time. The figures for 1938-39 and 1937-38 were the most recent available. The third column gave the average figures for the 5 year period from 1932-33 to 1936-37, also the most recent available.

It may be seen from these data the main producers of coffee were in the western hemisphere. The total production of tropical America was about 90 per cent of the world's total, with Brasil at the top, which alone was responsible for 60 to 70 per cent of the world crop. Colombia, with roughly a tenth, was second on the list. The third place was held by Indonesia, where the production on the estates in Java was added to that of the native peasants, mostly in southern Sumatra. The total for both groups of producers exceeded 1,000,000 quintals, which was a larger figure than that for any other country on the list of producers except Brasil and Colombia.

On the other hand, not all the coffee produced in Brasil was used for consumption. Enormous quantities had to be destroyed every year in order to limit the amount offered on the world market and to keep the prices up. The quantities destroyed were indicated in Table 7. In the cropping year 1937/38 the quantity was 8,700,000 quintales, or more than half of the year's crop.

A second interesting point in a study of the world's coffee production at that time, was the kind of coffee produced. C. arabica appeared to be the only species of coffee grown in all the American countries. Until 1873 this was true for the rest of the world, with the possible exception of small quantities of other species produced in Africa. Since that time several other species have been introduced into tropical agriculture and have taken their place in the production of the eastern hemisphere. However, the tropical American producers have stuck by the old kind. Brasil, Colombia, El Salvador, and all the other South and Central American producers grow only Arabica. Only the insignificant production of Dutch Guiana came from another species, C. liberica, while Trinidad produced some Robusta.

Many eastern countries which grew coffee, cultivated kinds other than Arabica. While until 1873 they had also produced only Arabica, at that time a new species was introduced, soon followed by others which showed resistance to leaf disease, a dominant factor in the coffee production in the eastern part of the world. At that time there was no trace of the disease in the Americas. It made its appearance in Asia when it was first observed in Ceylon in 1869, and soon it spread all over east Assia. It was also found in Africa, even in the country where Arabica originated, in Abyssinia. It did a great deal of harm in Madagascar, and it may have been responsible for the great development in the production of robustoid kinds on that island. In 1935 the future production was estimated at 30,000 to 35,000 tons of Kouilou, a kind closely resembling Robusta, and 5,000 tons of Arabica (Visscher, 1936, p. 1928). In 1938 Madagascar delivered 41,000 tons, of which 80 per cent was produced by the native population. A further increase was then expected (François, 1939, p. 156).

Although the bulk of the Indonesian crop consisted later of Robusta, the Arabica is still grown and heads the list of kinds other than Robusta which figure in the production in Indonesia. Most of the African coffee countries grow Arabica exclusively or mainly, but some, the Belgian Congo and Madagascar, have also gone in for Robusta.

THE PRODUCTION OF INDONESIA

If the production of Indonesia is studied, the great variety in the kinds of coffee produced becomes clear. It may be seen in the data from there for the last few decades that at the end of the last century the bulk of the crop from estates as well as from government plantings was still Arabica or the "Java coffee" but some Liberica was also produced. The government crop, which fluctuated in the years around 1900, between 100,000 and 200,000 piculs (60,000 and 120,000 quintals) was almost entirely composed of Java coffee. The production of Arabica, including both estate crops and government crops began to decline rapidly around 1909. After a last spasmodic rise in 1912 the decline continued, and soon the annual total was under 50,000 quintals. From 1905 on the production

of Liberica also declined steadily, but after 1909 the Robusta appeared on the list. In a couple of years Robusta climbed to first place, a position it has held up to the present day.

Some other kinds, hybrids and lesser species, have also appeared on the list. Figures for them are not reliable, for the quantities produced on individual estates were often small and might not be reported separately in the statements. Moreover, these lesser species and hybrids included many different kinds of coffee. Formerly the excellent statistical report on the annual coffee crops published by Gyselman and Steup had a separate column for the robustoid species such as Quillou, Canephora, and Ugandae. The heading of this column was later changed to Conuga. It seemed uncertain that the product of other species was not sometimes recorded as "conuga", nor was it certain that all the Congusta produced was mentioned under this heading. Such differences are, however, immaterial. The main point is that the figures showed how small the total production of these other kinds was compared with that of Robusta and even of Arabica.

PRODUCTION OF VARIOUS KINDS

As already stated, the bulk, of the Indonesian crop consists of Robusta. The second kind, Arabica, is produced in much smaller quantities, but it commands a much higher price. Both kinds are produced by estates as well as by natives. The figures indicate that, for the most part, estate Arabica comes from Java. The crop may vary a great deal from one year to another. In 1932 and 1934 Java had a very small crop, but in 1936 there was a bumper crop. With these variations the total Arabica crop of Indonesia, a few years later fluctuated around a figure of roughly 1,600 tons annually. The total for Java alone had been around 1,200 tons annually. There seemed to be a slight increase, compared with the previous period. The estate production of Arabica was unimportant compared with the total estate crop of Robusta, for which the average was above 50,000 tons. The figures showed what a rare article real Java coffee had become in Indonesia. The largest part of Arabica produced in Indonesia, has long come from native plantings. The total native production fluctuated around 6,000 annually.

There are some details on the principal centers of native Arabica production in past years. Sumatra ranked first, with an average of well over 3,000 tons per year. Compared with the Robusta production of Sumatra, which was over 50,000 tons in the same year, this figure seems insignificant. However, it should be remembered that the native Arabica was a fancy article bringing high price in contrast with the native Robusta, which had an even lower market value than estate Robusta. The islands of Bali and Lombok and the Celebes produced about half as much Arabica as Sumatra. The production of Timor was insignificant.

The estates in Java have gone on to produce a few thousand quintals of Liberica and hybrids. In recent years there has also been some production of Congusta, included in the "other kinds". Since 1938 Congusta, or Conuga, has been recorded separately in the statistics. In 1938 the total production was 699 quintals, in 1939 it was 2,751 quintals.

If the export figures for Arabica during the period 1933-1938 were compared with the total yield figures, it was apparent that practically no Arabica remained in the country for local consumption, except perhaps some in the centers of native production which escaped recording, since the figures for native production represented only the coffee exported.

It is of interest to have an idea of the quantities the various islands of the outer provinces contributed to Indonesian coffee production. Sumatra headed the group, for it was the largest producer of Robusta. The native production of Sumatra surpassed even the estate production of Robusta in Java. The quantities of Arabica were small in proportion to the Robusta. Here the native planting industry was also the main producer of this kind. Sumatra produced about the same quantity as the other native production centers together. Bali and Lombok together produced slightly more than Celebes.

In Bali and Lombok the Robusta production seems now to be increasing, while Arabica production there is an old established industry. Robusta was of fairly recent production. It appeared in the statistics for the first time in 1932 when 87 tons were delivered. In a few years it had attained the level of Arabica production in this region, and in 1938 it surpassed this figure. Although still far behind the Sumatra figure, it begins to attain a certain importance. This indicates that the eastern part of the archipelago can increase its Robusta production when prices become high enough to stimulate further extension. Arabica production has remained at about the same level for the last decade.

LOCAL CONSUMPTION AND EXPORTS

A large percentage of Indonesia's coffee production is absorbed in the country itself. Coffee is a popular beverage with the native population, and the centers of native coffee production undoubtedly consume fair quantities which are not included in the statistics. Statistics for the total pro-

duction by the native population are also incomplete in another respect. The yields of the native plantings in Java are not known, and from the tables in the publications of the Central Bureau of Statistics in Java it is clear that they are not included in the figures for the total production of Indonesia, calculated by adding the quantities exported by the native population in the outer provinces to the estate production of Indonesia (Anonymous, 1938, Table on p. 132). At that time the yield of the native plantings was estimated at 3.5 q./ha. On this basis the total yields would be as follows (loc. cit., p. 113):

| <u>Year</u> | <u>Estimated</u> |
|-------------|------------------|
| 1934 | 5,456 tons |
| 1935 | 5,623 tons |
| 1936 | 5,846 tons |
| 1937 | 6,157 tons |
| 1938 | 6,961 tons |

The trade statistics have indicated that roughly one third of the annual production is commonly consumed in Indonesia. However, the real quantity must be larger, since some of the locally consumed product escapes the statistics. The total consumption of coffee in Indonesia for the period 1928-1934 was estimated at an average of 38,500 tons (Scheltema, 1935, p. 1372). In 1937 the consumption of coffee was estimated as follows:

| <u>Region</u> | <u>Total</u> | <u>Per capita</u> |
|----------------|--------------|-------------------|
| West Java | 4,000 tons | 0.352 kg. |
| Central Java | 8,000 tons | 0.524 kg. |
| East Java | 16,000 tons | 1.06 kg. |
| Total for Java | 28,000 tons | 0.67 kg. |

It is sometimes said that in recent years the total consumption of coffee has declined in Indonesia, but it is far from certain that such a regression has actually taken place. Coffee is important not only as a product for export but also as an article of daily use in the country where it is grown.

The coffee exports from Indonesia go to many markets. Holland has been by far the principal importer of the Arabica produced in Indonesia. A good deal of the Indonesian Robusta also has been sold on the Amsterdam market. Information is available on the destinations of the coffee exports from Indonesia in the data for the period 1935-1938 (Anonymous, 1939d, p. 16). In it is also given the relative importance of the largest coffee markets of the world with figures representing the imports and deliveries of the principal markets for the years 1936/37 and 1937/38. The important position of Holland for the coffee trade may be seen there.

AREA UNDER COFFEE

A few figures may give an idea of the importance of the coffee plantings of Indonesia. The total area planted with coffee is known only for Java. For the outer provinces the area planted with coffee on estates is recorded, but no data are available on the very extensive native plantings. A reduction in the area planted with coffee on the estates seems to be in progress, probably because of the low level of market prices in recent years and the uncertain future of the market, with Brazil as a producer able to satisfy the entire world demand.

In a table compiled from data in successive issues of "Export Crops of the Netherlands Indies", 1931-1939 (1939), may be found the area planted in coffee and the production for the period 1928-39. The plantings were then composed of Robusta, Arabica, and other kinds. In this table the area in production and the immature area were not specified. For these two reasons the figures cannot be used for calculating average yields per hectare.

When the figures for estates are studied, the slight regression since 1933/34 is apparent. The native plantings in Java, which were not very important inasmuch as the total was actually only about 27,000 hectares, were extended for the period 1929-1934. Since 1934 the area of native planting has been extended very little, but it has not been reduced as has the area under cultivation by the estates. It may be that in recent years some of the coffee area on estates has been converted to rubber production. In 1939 a smaller extension of this latter crop was allowed under the restriction scheme, and on estates having both crops there must have been a tendency to replace the coffee, which had an uncertain future, with rubber, which had a much brighter market outlook. It is also probable that some coffee, planted as a catch crop, was cut out and not compensated for by new coffee plantings.

Coffee is often planted on estates which also have other crops (Anonymous, 1939a, 1941, p. 124). Only 94 of the 374 estates where coffee is reported to have been grown in Indonesia, planted coffee exclusively. Of the 280 estates where other crops were planted, 195 had plantings of Hevea rubber, and 130 had only Hevea in addition to coffee. The rubber may be planted in separate fields, or both crops may be combined in the same field. When the coffee is intended to be cut away at the time the rubber begins to bear or shortly afterwards, it is called a catch crop. In Besuki, fields were often planted with coffee and rubber in belts, with the idea of keeping both crops permanently. Coffee was planted in the same field with rubber on 155 estates. These planting systems have been explained in another chapter. There has been a close relationship between rubber and coffee in Indonesia.

The area of combined planting in coffee and rubber in Indonesia in 1935 was 29,786 hectares, or nearly a fourth of the total area planted with coffee (Anonymous, 1933a, p. 133). In 1939 this figure had dropped to 16,001 hectares, while the total area planted with coffee was then 99,167 hectares, making the combined planting about 16 per cent of the total.

In addition to areas planted with crops other than coffee, some estates still have land that is not yet under cultivation. However, the amount of such reserve land is dwindling every year, and there is very little chance, at least in Java, of increasing it. It may be seen from this that coffee estates in Java no longer have much reserve land. In 1936 the total area in estates planted with coffee and other crops was 202,637 hectares, while there was still an area of 173,711 hectares of unplanted land. In 1939 the total planted area had decreased to 163,546 hectares, with only 59,651 hectares of unplanted land. In the outer provinces the land reserve is much larger than the planted area.

Under these circumstances a material increase in the area under coffee cultivation on Java estates seems unlikely. Such an extension could take place only in the outer provinces. On the other hand, the native production especially in the outer provinces, can still be developed. In the eastern part of the archipelago there are certainly possibilities in this respect, but the present market prices and the very uncertain future of the market do not encourage attempts to establish coffee production in new regions or to extend the production of the existing centers.

LITERATURE CITED

(Editor's note:

I have taken certain liberties with this list of literature that Dr. Cramer included for this book. When his manuscript came to me it had pertinent citations at the end of all his chapters. This made for some convenience for readers that are accustomed to such type of handling. Many find it just as easy to turn to the back of a book, to one inclusive list. Some are even better satisfied with it there.

In this book, gathering all citations at the back reduced very numerous repetitions for such works as were necessarily referred to in several chapters. To have them listed only once was a great saving in space. Equally, if not more important, it gathered the names of the workers together in such manner that this list of those in one place is of primary value in itself.

When Dr. Cramer recorded his journal citations, he included in his original manuscript, as double security, both day and month of publication, in addition to the year. This was a good system, but after I went over these carefully, I finally decided that had he lived to see this book in print, he might well have been the first to suggest that only the years be used for the citations. To conserve space I also eliminated titles, degrees, and positions originally included with the names of authors.

Since I received the manuscript of this book, I have not had access to the old Dutch books, periodicals, bulletins, and special reports from which Cramer made most of these citations. It has been impossible to do all that would have been necessary to have accomplished a perfect editorial job in this matter. To have seen all these citations would have required a good piece of time working in Holland at least, and some would have necessitated a visit to the old library in Bogor (Buitenzorg), in Java.

Here, at the Inter-American Institute of Agricultural Sciences in Turrialba, Costa Rica, the Librarian and her Assistant, to whom I express especial and grateful acknowledgment, verified many of the old citations. As many as could be found in original publications, or in bibliographical tools, were thus verified.

However, many of Cramer's original citations are still as he gave them and are so indicated by an asterisk (*). Every mention of an article in the text has been compared with its presence in the Literature Cited. Corroboration of exact citations is further difficult, in some cases, because Cramer was writing under severe circumstances as a prisoner of war being harshly treated.

It will be noted that page numbers mentioned in Cramer's discussions are referable to pages given as numbers following titles under dates. The reader can refer to these, along with the year, in tracing back certain articles. In no case has there been such duplication of page numbers as to cause confusion. F. L. W.)

A. 1924. see Anonymous 1924.

ABEKELE, M. van den. 1938. Quelques données sur la sélection du café dans la "Proefstation Midden-en-Oost-Java". Bulletin Agricole du Congo Belge 29(1):136-140.

ALBERTS, G. A. 1915. Lamtore als Schaduw. Malang. Proefstation Mededeeling no. 10. 10 p.

* _____ 1924. Lamtore or Dadap? Ned.-Ind. Rubber en Thee Tijdschrift (Buitenzorg) 9(13):432.

* ALTONA, TH. 1913. De bestemming te geven aan de op te koffen koffie-reserven. Tectona 6:296.

AMENT, C. C. 1933. Een en ander over vegetatieve vermenigvuldiging van koffie. Bergcultures 7(4):115-120.

_____ 1936. Wertel-onten van koffie. Archief voor de Koffiecultuur 10(1):1-13.

_____ & GANDRUP, J. 1934. Productiecijfers van koffietuinen; de onderstamproef op Kebon Deli. Bergcultures 8(25):577-579.

ANDRADE, E. N. 1914. A cultura do café nas Indias Neerlandesas. Sao Paulo, Brasil, Secretaria da Agricultura. 118 p.

- + ANONYMOUS. 1873. Handleiding voor de gouvernements - Koffiecultuur. Batavia.
- + _____ 1876. Liberian coffee: questions asked by the Director of the Royal Botanic Gardens of Ceylon, with replies thereto. 3 p.
- + _____ 1878. Liberian coffee in Ceylon. Compiled from the Ceylon Observer. Colombo. p. 142.
- + _____ 1879. Bladsiekte bij de koffieboomen (Hemileia vastatrix). Batavia. Nijverheid en Landbouw, Tijdschrift 24:188-190.
- + _____ 1888. Eenige opmerkingen omtrent de koffie-bladsiekte. Indische Mercur 11(45):563.
- + _____ 1888a. Liberian coffee at the Straits Settlements. Kew Bulletin no. 22:261-262.
- + _____ 1888-1889. Gouvernements Koffiecultuur; rapport v. d. Staatscommissie, benoemd bij K. B. v. 14-10-1888. 's Gravenhage.
- + _____ 1890. Koffieziekten in Brazilië en op Java. Tijdschrift voor Land- en Tuinbouw en Boschcultuur 5:4. (See also pages 38, 141 and 252).
- + _____ 1890a. Liberian coffee. Kew Bulletin of Miscellaneous Information no. 47. p. 245.
- + _____ 1890b. Onderzoekingen van Dr. Soltwedel insake de Serehsiekte. Tijdschrift voor Land en Tuinbouw en Boschcultuur in Ned-Oost-Ind. 5. pp. 145-146.
- + _____ 1890c. Verval der koffiecultuur in Ceylon. Indische Mercur 13(6):73.
- + _____ 1892. Liberia Koffie. Indische Mercur. 15(39):581.
- + _____ 1893. Hybride iets over de Liberia met Java-Koffie. Indische Mercur. 15:215.
- + _____ 1894. Maragogipe coffee. Kew Bulletin of Miscellaneous Information 1894:163-164.
- + _____ 1897. Het enten van koffie hybriden. Teysmannia 7:529-531.
- + _____ 1897a. Hybriden - ente de van Klein - getas. Indische Landbouw-Courant. p. 95.
- + _____ 1897b. Liberia koffiepulper "Lyon". Indische Mercur 20(3):27.
- + _____ 1899. Koffiecultuur. Indische Mercur 22(1):4.
- + _____ 1900-1901. Commissie tot winning van saadkoffie; resumé van het verhandelde op de vergaderingen van de Commissie van 7 tot 12 Januari, 1901. Koffiegids 2:1321.
- + _____ 1900-1901a. Veredeling van koffie. Koffiegids 2:141-147.
- + _____ 1901. De proeftuin van Dr. Treub. Indische Mercur 24(4):61.
- + _____ 1901a. Java - Liberia. Indische Mercur 24(2):29; (8):233.
- + _____ 1901b. Koffie en slaap. Indische Mercur 24(4):67.
- + _____ 1901-1902. Slaagt het enten van Java en Margogype op Liberia? Cultuurgids 3:285.
- + _____ 1902. Koffie een coffeine - vrije. Teysmannia 12:211.
- + _____ 1903. Der Kaffee. (Herausgeg. vom Kaiserl. Gesundheitsamt.) Berlin. p. 55.
- + _____ 1904. Koffie en cacao; over wit het jaarverslag der Soekaboemische Landbouw - vereniging. Cultuurgids 6:138.

- * ANONYMOUS. 1904-1905. Hybriden-koffie. Cultuurgids 6:987.
- * _____ 1904-1905a. Nieuwe Koffieboomen van de Westkust van Africa. Cultuurgids 6:517.
- * _____ 1905. De wenschelijkheid van nieuw bloed voor de Liberia - Koffie. Cultuurgids 7:44, 47, 123-175. (Een discussie over Liberia-koffie, p. 561).
- * _____ 1905a. Een schaduwboom (Degueida microphylla). Teysmannia 16:316.
- * _____ 1907. Kan de Klein - Getas hybride een fijne kop koffie leveren? Cultuurgids 8:783.
- * _____ 1907a. De koffiecultuur op Java. Cultuurgids 8:475, 486.
- * _____ 1907b. Liberia - en robusta bibitcommissie; advies voor het winnen van zaad van Coffea liberica en robusta. Teysmannia 18:190, 197.
- _____ 1913. Coffee diseases in East Africa. Kew Bulletin of Miscellaneous Information 5:168-171.
- * _____ 1915. Robusta - koffie. Teysmannia 26:203.
- * _____ 1917. Beoordeeling van robusta - achtige koffie - soorten. Ned. Ind. Landbouw Syndicaat Publicatie 9(4):ix.
- * _____ 1918. Gouvernements - Koffiecultuur. In Encyclopedies van Nederlandsch-Indië, 1918. Dl. 2. p. 385; 1932:811-812.
- * _____ 1924. Bangelan blijft bij landbouw. Ned. Ind. Rubber en Thee Tijdschrift (Buitenzorg) 9(13):431.
- _____ 1925. Koker - snoei in gesloten koffie - aanplant. Indische Culturen 10(1):21.
- * _____ 1926. Bevolkingscultuur een en ander over de - van robusta - Koffie ter Sumatra's Westkust en in Palembang. Dept. voor Landbouw N. en H. Afd. Landbouw. p. 1.
- * _____ 1927. Koffieproductie; een fenomenale. Indische Mercur 50(6):93.
- _____. 1928. Coffee from Mauritius, Sierra Leone and Sudan. Great Britain. Imperial Institute. Bulletin 26(4):418-423.
- * _____ 1930. Concerning the technical manufacture of "caffeine-free" coffee. Spice Mill 53:728.
- _____ 1930a. Oversicht van de ziekten en plagen bij Koffie in het jaar 1929. Bergcultures 4(17):433-434.
- _____ 1931. De proeftuin Bangelan. Bergcultures 5(34):929-930, 933.
- _____ 1931a. Le caféier Robusta amélioré de Nouvelle Calédonie. Revue de Botanique Appliquée et d'Agriculture Tropicale 11(118):461-462.
- _____ 1931b. Recent research on empire products: coffee. Great Britain. Imperial Institute. Bulletin 29(2):197-198.
- * _____ 1932. Korte gids voor bezoekers van de gouvernements koffie - onderneming "Bangelan". Buitenzorg. p. 2.
- * _____ 1932a. Oud - necht, Coffea arabica. Bandoeng. Algemeen Landbouw Weekblad 17(15):312.

- ANONYMOUS. 1932b. Physiologische rassen bij Hemileia. (Abstract). *Bergcultures* 6(48):1303.
(Translation of abstract in *Nature* 129:510. 1932).
- + _____ 1933. Arabica - selectie. *Bandoeng. Algemeen Landbouw Weekblad* 18(4):62.
- _____ 1933a. Coroa coffee. *Kew Bulletin of Miscellaneous Information* no. 8. pp. 413-414.
- _____ 1933b. Eenige mededeelingen over Kent's arabica - koffie. *Bergcultures* 7(3):84-85.
- + _____ 1934. Congensis - koffie. *Bergcultures* 8(28):630; (28):653.
- _____ 1934a. De takeran. *Bergcultures* 8(3):47-48.
- + _____ 1934b. Over de oorsaauder schadelijke weking van koffie. *Pharmaceutisch Weekblad*
(Amsterdam) 71:1345.
- + _____ 1936. Koffie - rooikeur. *Bali* no. 17. *Extra Bijvoëgsel Javasche Courant* no. 21.
- + _____ 1937. Koffie - aankopen; Duitsche - voor industriele doeleinden. *Bergcultures*
11(29):1054, 1193.
- _____ 1937a. La taille du caféier au Congo Belge. *Agriculture et Elevage au Congo Belge*
(Bruxelles) no. 4. p. 64 (Cited in *Review de Botanique Appliquée et d'Agriculture*
Tropicale 17:479).
- + _____ 1938. Landbouw - exportgewassen van Ned.-Indië. *Batavia, Centraal Kantoor voor de*
Statistiek, Jaarbericht no. 1. pp. 132-133.
- + _____ 1938a. Keitschrift für Untersuchung der Lebensmittel. Cited in: *Pharmaceutisch*
Weekblad (Amsterdam) 75(48):1337.
- _____ 1939. De hulpgewassen bij de meerjarige cultures. *Bergcultures* 13(48):1669-1674;
(49):1696-1706.
- + _____ 1939a. Export crops of the Netherlands Indies in 1939. (De landbouw - exportgewassen
van Nederlandsch-Indië in 1939). *Batavia, Central Kantoor voor de Statistiek, Kaarbericht*
no. 4. 1941. pp. 1-288.
- + _____ 1939b. In welke mate bestaat er - in prijs tusschen de Zuid - en Middel Amerikaansche
arabica - Koffie en robusta? *Economische Weekblad* (Batavia) 8:126.
- + _____ 1939c. Verwerking van koffie tot glas. *Bergcultures* 13(40):1397.
- _____ 1939d. Jaaroverzicht Hand. Kolon. Product. 1938. *Indische Mercur*. p. 16.
- + _____ 1940. Koffie als grondstof voor de vervaardiging van Platische stoffen. *Bergcultures*
14(11):347.
- + _____ 1940a. Ordinance on coffee packing. *Staatsblad* 1940. no. 535. (Also in Dutch in
Bergcultures 14(49):1553.)
- + _____ 1941. Landbouw - exportgewassen van Ned.-Indië in 1939. *Batavia, Centraal Kantoor voor*
de Statistiek, Jaarbericht no. 4. p. 141, 146.
- ANSTEAD, R. D. 1915. *Coffee; its cultivation and manuring in South India*. Bangalore. 3 p.
- _____ 1921. The variability of yield of individual coffee bushes. *Tropical Agriculturist*
(Ceylon) 56(6):338-339.
- _____ 1938. Note sur la qualité du café. *Revue de Botanique Appliquée et d'Agriculture*
Tropicale 18(206):724-725.

- ARENS, P. 1921. Koffiebessenboek. Ned.-Ind. Landbouw Syndicaat Publicaties 13:314-322. (Summary in Indische Mercur 44(17):286.)
- * ARISZ, W. H. 1924. Over selectie van Java - koffie. Ned.-Ind. Rubber en Thee Tijdschrift 9:40.
- _____ 1926. De Proeftuin voor de Bergcultures van het Besoekische Proefstation II. Besoekische Proefstation Mededeeling no. 40. pp. 3-13.
- BACCHI, O. 1941. Observacoes citológicas em Coffea. VII. A macrosporogênese na variedade "Monosperma". Bragantia 1(6):483-490.
- * BACKER, C. A. 1936. Verwilderings - centra op Java van uithemische planten. Tropic. Natur, Jubileumuitgave. p. 51.
- _____ & SLOOTEN, D. F. van. 1924. Geïllustreerd handboek der Javaansche thee - en kruiden en hunne beteekenis voor de cultuur. Batavia, Ruygrok. 240 p.
- BAGALSO, C. C. 1932. Top working old coffee trees which are poor yielders. Philippine Agriculturist 21:491-504.
- BAILLON, H. E. 1880. Histoire des plantes. Paris. Vol. 7, 277 p.
- BALLY, W. 1920. Selectie bij rubber en koffie. Midden - Java Proefstation no. 33. pp. 1-12.
- * _____ 1920a. Vierde verslag van de robusta selectie op Banaran. Midden - Java Proefstation Mededeeling no. 35. p. 8.
- _____ 1922. Indrukken van een reis naar de Lampongs en naar West - Java. Koffie-bessenboek Fonds. Mededeeling no. 3. pp. 43-48.
- _____ 1926. 25 jaar robustacultuur. Archief voor de Koffiecultuur 1(4):157-166.
- _____ 1928. Eerste rapport over de topsterfte van de koffie in de residenties Benkoelen en Palembang. Archief voor de Koffie-cultuur 2(2):53-132.
- _____ 1928a. Korte Mededeelingen over topsterfte bij koffie in Zuid - Sumatra. Bergcultures 2(33):979-982.
- _____ 1930. De zwarte wortelchimmels van koffie. Archief voor de Koffiecultuur 4(1):1-19.
- _____ 1931. Bestrijding van djamoer oepas in de koffie. Bergcultures 5(28):755-756.
- _____ 1931a. Handboek voor de koffiecultuur. Amsterdam, J. H. de Bussy. 212 p. (Coffee diseases pp. 29, 66, 98, 101, 109, 123, 135.
- _____ 1932. Bemesting van koffietuinen, die door aaltjes besmet zijn. Archief voor de Koffiecultuur 6(2):43-56.
- _____ 1933. Le café en 1931 et 1932; questions économiques et techniques. Rome, Institut International d'Agriculture pp. 117, 162.
- _____ & REYDON, G. A. 1931. De tegenwoordige stand van het vraagstuk van de wortelaaltjes in de koffiecultuur. Archief voor de Koffie-cultuur 5(2):23-216.
- BANGELAN. 's Lands Plantentuin. 1909. Verslag. p. 189.
- * BARON SALAK. 1916. Robusta coffee in Java. Tropical Agriculturist (Ceylon) 46:77.

- + BAUD, H. W. L. 1894. De cultuur van Liberia koffie en de daaraan verbonden kosten. Tijdschrift Nijverheid Landbouw Ned.-Ind. 47:298, 305.
- HEGEMANN, H. 1926. Nieuwe methoden voor de ontsmetting van koffiezaad. Arvhief voor de Koffie-cultuur 1(5):208-216.
- _____ 1928. Groene luis bij koffie. Bergcultures 3(17):423-431.
- + _____ 1928-1929. Statische methode en takkenboek. Verslag 9 Vergard. Vereen. Proef-station Person. p. 21.
- _____ 1930. Nieuwe methoden voor de ontsmetting van koffiezaad. II. Archief voor de Koffiecultuur 4(2):45-55.
- BENGIS, ROBERT O. 1936. Oxidation of fat fraction of roasted coffee. Industrial & Engineering Chemistry (Industrial edition) 28(3):290-293.
- BERG, N. P. van den. 1879. Historisch - statistische aantekeningen over de voort brenging en het verbruik van koffie. Tijdschrift Nijverheid Landbouw Ned.-Ind. 24:427-453.
- + BERGCULTURES. 1931, 1932, 1937, 1940. (No titles.) 1931, p. 5; 1932, p. 254; 1937, p. 299; 1940, p. 1553.
- BERKELEY, M. J. & BROOME, C. E. 1873. Enumeration of the fungi of Ceylon. Pt. II. Linnean Society (London). Journal 14:29-140.
- + BERKHOUT, A. H. 1893. De koffiecultuur op Java. Indische Mercur 16(6):76.
- + _____ 1940. Mijne bemoeienissen met de koffiecultuur. Tectona 33:45-46.
- BERTRAND, G. 1902. Recherche et dosage de la caféine dans plusieurs especes de café. Agriculture Pratique des Pays Chauds 2(8):211-213.
- _____ 1905. Note sur les cafés sans caféine. Paris. Academie Sciences. Comptes Rendus 141(3):209-211.
- + BESOEKISCHE LANDBOUW PROEFSTATION. 1929. Notulen van de Algemeene Vergadering gehouden op 26 maart, 1929. Dinsdag. p. 5.
- + _____ 1940. Notulen van de Algemeene Vergadering. Bergcultures 14(50):1606, 1608.
- BETREM, J. G. 1931. Voorloopige mededeeling over het smeeren met bessen-boeboeksmeer als voorbehoed middel tegen takkenboek. Bergcultures 5(30):799-801.
- _____ 1932. Takkensterfte en boek. Bergcultures 6(3):57-64.
- _____ 1932a. Witte luis. Bergcultures 6(22):552-557, 559-561.
- _____ 1933. Orienteerende proeven met blauwzuurgas tegen witte luis en takkenboek. Archief voor de Koffiecultuur 7(2):84-103.
- _____ 1934. De takkenboek als veroorzaker van takkensterfte. Bergcultures 8(4):73-82, 84-87.
- _____ 1935. De oeconomie van de bessen-boeboekbestrijding. Bergcultures 9(11):1223-1229.
- + _____ 1935a. Information given in a meeting of the Malang Landbouw Vereeniging. Berg-cultures 9(19):432.
- _____ 1936. De bestrijding van de witte luis. Archief voor de Koffiecultuur 10(2):187-217.

- BETREM, J. G. 1936a. Gegevens omtrent de biologie van de dompolanluis (Pseudococcus citri) en de lamtoro luis (Ferrisia virgata). Archief voor de Koffiecultuur 10(2):43-84.
- _____ 1936b. De oecologie en epidemiologie van de witte luizen. Archief voor de Koffiecultuur 10(2):85-186.
- _____ 1938. Takkensterfte takkenboek en snoei in verband met de productie bij koffie. Bergcultures 12(16):476-486.
- Bevolkingscultuur. 1926. See Anonymous 1926.
- BLAKESLEE, A. F. & AVERY, A. G. 1937. Methods of inducing doubling of chromosomes in plants by treatment with colchicine. Journal of Heredity 28(12):393-412.
- BLANKERT, W. H. 1933. De vegetatieve vermeerdering van zaadloze of zaadarme lamtoro (Leucaena glauca). Bergcultures 7(24):675-679.
- * BLIJ, C. H. de. 1907. Het snoeien van Liberia koffie. Cultuurgids 8:486-487.
- BOER, H. J. de. 1937. Eenige gegevens over de bevolkings - koffiecultuur in Kerintji (Sumatra's Westkust). Kolon. Studien. p. 201.
- * BOIS, E. du. 1900-1901. Over de bladsiekte. Koffiegids 2:530, 534.
- * _____ 1901-1902. Een koffiesoort, die de aandacht schijnt te verdienen. Cultuurgids 3:136.
- BOOM, S. 1912. Is het raadzaam koffiesaad ontdaan van de hoornschild, uit te leggen? Malang Proefstation. Mededeeling no. 4. pp. 1-3.
- BOONSTRA, A. E. H. R. 1934. Physiologisch onderzoek ten dienste van de planten veredeling. Landbouw Hoogeschool Mededeeling 38(1):1-99.
- BOUTILLY, V. 1900. Le caféier de Libéria, sa culture et sa manipulation. Paris. 137 p.
- BRAAK, C. 1921. Het klimaat van Nederlandsch-Indië. I. Verhand. Kon. Magn. en Meteor. Observatorium, Batavia. no. 8. p. 492.
- BREMER, G. 1934. De cytologie van het suikerriet; een cytologisch onderzoek van een 50 - tal in 1929-1930 op Java geïmporteerde reitsoorten. Soerabaja. Proefstation van de Java - Suikerindustrie. Mededeeling no. 5. pp. 141-166.
- BRILL, H. C. 1916. Leucaena glauca as a substitute for coffee. Tropical Agriculturist (Ceylon) 47:224.
- BROWN, A. 1880. The coffee planter's manual. Colombo. 246 p.
- * BRUGGE, W. C. van. 1898. Koffie; iets uit de oude doos. "Koffie" op zijn Sulthaans in Arabien en anders Turksche plaatsen. Indische Mercur 21(29):460.
- BRUIJNING, F. F. 1915. Mantsaka - koffie. Onderzoekingen Rijkslandbouw Proefstation. Verslag no. 18. pp. 114-146.
- BRUXELLES. MINISTERE DES COLONIES. 1908. Manuel pratique de la culture du caféier et du cacaoyer au Congo Belge. 96 p.
- * BUITENZORG. 'S LANDS PLANTENTUIN. 1873-1904. Verslags, 1873, 1876, 1877, 1878, 1881, 1882, 1884, 1885, 1892, 1896, 1898, 1901, 1902, 1903, 1904.
- * BULL, W. 1897. De nieuwe Liberia - koffie; Coffea liberica. Ned.-Ind. Nijverheid Landbouw Tijdschrift 23. pp. 518, 520.

- BULLOCK, A. A. 1930. Nandi coffee. Kew Bulletin of Miscellaneous Information 1930. p. 401.
- BURCK, W. M. 1884. Sur l'organisation florale chez quelques Rubiaceés. Buitenzorg. Jardin Botanique. Annales 4. pp. 12, 53.
- _____ 1887-1889. Over de koffiebladziekte en de middelen om haar te bestrijden. 's Lands Plantentuin Mededeeling 4:1-61; 5:1-4
- _____ 1896. Over koffie - producties in verband met den regenval. Teysmannia 7:1-7.
- + _____ 1896a. Over de oorzaken van den achteruitgang van de gouvernements koffiecultuur op Java. Tijdschrift Binnenl. Bestuur 12:303, 315, 363, 383.
- BURKILL, I. H. 1935. A dictionary of the economic products of the Malay Peninsula. London, Crown Agents. vol. 1, pp. 619-628.
- + BURRE BOERE, 1900-1901. Uittreksels uit: "De koffiecultuur in het Agome - gebergte" van Henrici, E. H. en "Koffie" van Kumpel, J. Koffiegids 2:290, 294.
- + BUSSE, W. 1902. Eine neue koffee - art aus Deutsch - Oost - Afrika. Tropenpflanzer 6:142.
- + BUTIN SCHAAP, D. 1898. Een nieuwe Liberianpulper. Indische Mercur 21(7):78, 98.
- _____ 1901. Het enten van Java - en Maragogye koffie op Liberia. Nieuwe Gids (Koffiegids) 3:220.
- + _____ 1901a. Schaap or Riemsdijkpulper? Indische Mercur 24(6):100.
- BUTLER, E. J. 1918. Fungi and disease in plants. Calcutta, Thacker, Sprink & Co. 547 p.
- BUTTIKOFER, 1891-1892. Reisebilder aus Liberia. Teysmannia 2:528; 3:528.
- CANDOLLE, A. de. 1883. Origine des plantes cultivées. Paris, G. Bailliere & Co. vol. 8. 379 p.
- CARVALHO, A. 1939. Causas da baixa produtividade do C. arabica L. var. Margogipe Hort. ex Froehner. Sao Paulo, Brasil. Instituto Agronómico de Campinas, Boletim Técnico no. 59. 45 p.
- _____ 1941. Genetica de Coffea. IV. Instabilidade do par de alelas na-na de Coffea arabica L. Bragantia 1(6):453-466.
- CASTELLANI, E. 1938. La ruggine del caffè nel Harar. Agricoltura Coloniale 32(8):337-345.
- CELOSSE, N. J. 1933. Het schaduwvraagstuk. Bergcultures 7(16):448-454.
- _____ 1934. Congensis koffie. Bergcultures 8(13):288-290.
- + _____ 1934a. De invoer van de robusta in Nederlandsch-Indië. Bergcultures 8(40):952.
- + _____ 1937. Een raad aan Albizia - planters. Bergcultures 11(10):322.
- _____ 1940. Goed opletten! (Iets over een krachtig groeiende lamtorosoort). Bergcultures 14(16):526-527.
- + CENTRAAL KANTOOR VOOR DE STATISTIEK. 1931. De landbouw exportgewassen van Nederlandsch-Indië in 1930. Batavia. Mededeeling no. 97. pp. 142, 145.
- Ceylon Observer, 1878. See Anonymous 1878.

- CHENEY, R. H. 1925. "Coffee; a monograph of the economic species of the genus Coffea L." New York, New York University Press. 244 p.
- _____ 1927. Lecture on coffee and its effects. *Spice Mill* 50(5):819-822.
- * CHEVALIER, A. 1903. Note complémentaire sur le caféier de Senoussi (Coffea excelsa). *Revue des Cultures Coloniales* 13(128):37-38.
- * _____ 1903a. Notes préliminaires sur quelques caféiers sauvages nouveaux ou peu connus de l'Afrique Centrale. *Revue des Cultures Coloniales* 12(124):257, 258.
- _____ 1905. Un caféier nouveau de l'Afrique Centrale. Paris, l'Académie des Sciences. *Comptes Rendus* 140(8):517-520. (Translation in *Cultuurgids* 7:324).
- _____ 1905a. Een nieuwe koffiesoort van Central - Afrika; les caféiers sauvages de la Guinée Française. Paris, l'Académie des Sciences. *Comptes Rendus* 140(22):1472-1475.
- _____ 1907. Sur le caféier nain de la Sassandra, Coffea humilis A. Chev. Paris, l'Académie des Sciences. *Comptes Rendus* 145(5):348-350.
- * _____ 1908. Sur l'origine du caféier de Liberia. *Agricultura Tropica* 79:8.
- * _____ 1908a. Un nouveau caféier nain. *Agriculture Pratique des Pays Chauds* 8:79, 81.
- _____ 1926. Nouveaux documents sur le caféier Chari. *Revue de Botanique Appliquée et d'Agriculture Tropicale* 6(63):667-675.
- _____ 1929. Les caféiers du globe. Fasc. I. Généralités sur les caféiers. Paris, Paul Lechevalier. (*Encyclopedie Biologique* no. 5). pp. 5, 6, 8, 87, 90, 92, 97, 98, 103, 121, 132.
- _____ 1929a. Comment s'est comporté le Coffea excelsa au Brésil. *Revue de Botanique Appliquée et d'Agriculture Tropicale* 9(89):23-26.
- _____ 1931. La culture du caféier en Nouvelle Calédonie. *Revue de Botanique Appliquée et d'Agriculture Tropicale* 11(115):174-176.
- _____ 1937. "Les plantations de café au Congo Belge; leur histoire (1881-1935) leur importance actuelle". (Review of book by E. Leplae). *Revue de Botanique Appliquée et d'Agriculture Tropicale* 17(185):66-68.
- _____ 1937a. Un nouveau caféier sauvage de Madagascar a grains sans caféine. *Revue de Botanique Appliquée et d'Agriculture Tropicale* 17(195):821-826.
- _____ 1938. Essai d'un groupement systématique des caféiers sauvages de Madagascar et des îles Mascareignes. *Revue de Botanique Appliquée et d'Agriculture Tropicale* 18(208):825-843.
- _____ 1939. Sur quelques caféiers et faux caféiers de l'Angola et du Mayombe portugais. *Revue de Botanique Appliquée et d'Agriculture Tropicale* 19(214):396-407.
- _____ & TROCHAIN, J. 1939. Un nouvel arbre d'ombrage pour le caféier. *Revue de Botanique Appliquée et d'Agriculture Tropicale* 19(214): 430-431.
- GIUPKA, P. H. 1937. *Kaffee; ein lehrbuch in enger anlehnung an die Praxis*. Hamburg. p. 56.
- COLEMAN, L. C. 1931. The improvement of coffee in the Dutch East Indies. *Mysore State Department of Agriculture Bulletin* 15. 19 p.
- _____ 1934. The coffee-planting industry of South India. *Empire Journal of Experimental Agriculture* 2(8):303-314.

- COLEMAN, L. C. & KANNAN, K. K. 1918. Some scale insect pests of coffee in South India. Mysore State Department of Agriculture Bulletin (Entom. series) no. 4. 66 p.
- Commissie tot winning van zaadkoffie. 1900-1901. See Anonymous 1900-1901.
- CONGO BELGE. INSTITUT NATIONAL POUR L'ETUDE AGRONOMIQUE (INEAC). 1939. Rapport annuel, 1939, lere partie. pp. 100, 178, 179, 182.
- + COOLHAAS, C. 1938. Conuga marktkoffie. Bergcultures 12(7):188, 189.
- _____ 1939. Korte inleiding over het takentvraagstuk naar aanleiding van de artikelen van Ir. Meijer en Dr. Hille Ris Lambers. Archief voor de Koffiecultuur 13(2):47-50.
- + _____ 1939a. Een overzicht van de werkzaamheden van het Proefstation M. O. J. in 1938. Bergcultures 13(18):557, 559.
- _____ 1941. Wat kan men met tuinverenting bereiken? Bergcultures 15(3):62, 63, 64, 70, 71.
- CORPORAAL, J. B. 1921. De koffiëbesborder op Sumatra's Oostkust en Atjeh. Mededeeling Algemeen Proefstation Alg. Ver. Rubberplanters Oostkust Sumatra, Ser. no. 12. 20 p.
- COSTER, CH. 1932. Wortelconcurrentie en aanverwante vraagstukken. Bergcultures 6(43):1150-1155.
- + COSTERUS, J. C. & SMITH, J. J. 1895. Teratology studied in the tropics. Buitenzorg. Jardin Botanique. Annales 13:97, 118.
- CRAMER, P. J. S. 1906. Nematoden in wortels van Coffea robusta. Teysmannia 17:191.
- + _____ 1907. De achteruitgang van de Liberia koffië op Java; welke Loding moeten wij tegenover haar aannemen? Verslag 9de Congres. Syndikat Koffiecultuur en Bergcultures in Ned.-Ind. pp. 720, 725, 732, 735.
- + _____ 1907a. Overzicht der resultaten, bereikt met het Liberia - koffië - zaad uit Suriname. Teysmannia 18:710, 712, 718, 719.
- + _____ 1907b. Selectie van koffië. Teysmannia 18:131, 144, 219, 278, 286, 289, 612.
- + _____ 1908. Coffea excelsa. Teysmannia 19:595-602.
- + _____ 1908a. Coffea stenophylla. Teysmannia 19:403.
- + _____ 1908b. Mutaties bij Coffea robusta. Teysmannia 19:531, 535.
- _____ 1908c. Nieuwe en minder bekende koffiësoorten. Teysmannia 19:300-313.
- + _____ 1908d. Uganda koffië. Teysmannia 19:733.
- + _____ 1908e. Verslag van den Botanist a/d Afd. Koffië over 1906. Teysmannia 19:11, 12, 63, 66-67.
- + _____ 1909. Coffea congensis. Teysmannia 20:3, 6, 37, 73, 77, 78, 79, 80.
- + _____ 1909a. De eerste generatie der Abeokuta - koffië op Java. Teysmannia 20:475.
- + _____ 1909b. Mededeeling - en over de robusta - koffië. Ned.-Ind. Landbouw Syndicaat Publicatie 1(16):7, 8.
- + _____ 1909c. Plantsoorten geschikt voor groene bemesting en de wijze van toepassing. Ned.-Ind. Landbouw Syndicaat Handel. 10de Congres, 27-28 Aug., 1909, Bandoeng. 2e Ged. p. 35.
- + _____ 1909d. Robusta - koffië als catchcrop voor Hevea. Teysmannia 20:540.

- + CRAMER, P. J. S. 1909e. Vegetatives vermenigvuldiging van Deguelia microphylla. Teysmannia 20:238.
- + _____ 1910. De herleving van de koffiecultuur op Java. Indische Mercur 33(20):379, 380.
- + _____ 1910a. Une méthode de sélection applicable a l'agriculture tropicale. Buitenzorg. Jardin Botanique. Annales 3(1):461-472.
- + _____ 1910b. Robusta - koffie of hybridenenten? Indische Mercur 33(29):870.
- + _____ 1913. Gevens over de variabiliteit van de in Nederlandsch-Indië verbouwde koffiesoorten. Batavia. Uitgaande Dept. Landbouw Mededeeling no. 11. 696 p.
- + _____ 1914. Plan voor de inrichting van een selectietien voor meerjarige gewassen in Nederlandsch-Indië. Ned.-Ind. Landbouw Syndicaat Publicatie 6(16):651, 653.
- + _____ 1914a. Wild rubber and selection. Rubber Recueil. p. 13.
- + _____ 1916. Coffea arabica var. Pasoenah. Teysmannia 27:205, 206, 208.
- + _____ 1916a. Excelsa - koffie. Teysmannia 27:211, 213, 215, 217, 221.
- + _____ 1916b. De teelt van zaadkoffie op Bangelan. Teysmannia 27:390-410.
- + _____ 1916-1917. Robusta, Hevea en de toekomst. Ned.-Ind. Rubber en Thee Tijdschrift (Buitenzorg) 1:353, 374, 514.
- + _____ 1918. De groote landbouw in Zuid - Sumatra Eerste Zuid - Sumatra Conferentie. Congres Onderwerp 3. pp. 20, 27.
- + _____ 1918-1919. Coffees of the Dutch East Indies. Tea and Coffee Trade Journal 1918:316, 419, 420; 1919:22, 25, 27, 118, 120.
- + _____ 1919-1920. Een uitdunningsproef met 17 - Jarige Hevea op Bangelan. Archief voor de Rubbercultuur 3:49; 4:52.
- + _____ 1923. Excursie naar Bangelan. Ned.-Ind. Landbouw Syndicaat Bulletin 15:1576, 1577.
- + _____ 1923-1924. Oude werkwijzen en nieuwe mogelijkheden. Ned.-Ind. Rubber en Thee Tijdschrift (Buitenzorg) 8:570, 605, 606, 632, 633, 634; 9:19, 100, 148, 171, 173, 174.
- + _____ 1924. Congensis koffie. Ned.-Ind. Rubber en Thee Tijdschrift (Buitenzorg) 9:41, 42, 43.
- + _____ 1924a. Grafting in coffee culture. Tropical Agriculturist (Ceylon) 62(2):76-86; (3):147-155; (5):272-279; (6):336-347.
- + _____ 1924b. Onze koffieproductie. Ned.-Ind. Rubber en Thee Tijdschrift (Buitenzorg) 9:41, 43, 228, 230, 231, 244, 245, 280.
- + _____ 1924c. Een snelgroeijende groenbemester, geschikt voor rubber en koffie: Crotalaria anagyroides. Ned.-Ind. Rubber en Thee Tijdschrift (Buitenzorg) 9:284.
- + _____ 1926. Institutes for research work in the interest of agriculture in the Netherlands Indies. Honolulu, Pan-Pacific Research Institution. Journal. vol. 1 no. 2.
- + _____ 1927. La culture de café aux Indes Néerlandaises; rapport des Conf. Intern. Trop. Products, Paris, 1927. London, Greville Montgomery. 334 p. (Review in Tropenpflanzer 32(5):224. 1929).

- CRAMER, P. J. S. 1927a. Het karakteristieke van de saadteelt op Bangelan. *Bergcultures* 2(4):87-89.
- _____ 1927b. Plant - materiaal van Bangelan. *Bergcultures* 1(43):1251-1257.
- _____ 1928. Groeicijfers bij koffie. Buitenzorg. Algemeen Proefstation Landbouw Mededeeling no. 26. (Also in *Archief voor de Koffiecultuur* 2(1):4-52).
- _____ 1934. Early experiments on grafting coffee in Java. *Empire Journal of Experimental Agriculture* 2(7):200-204.
- _____ 1935. L'amélioration du matériel a planter dans la culture du caféier aux Indes Néerlandaises. *Agronomie Coloniale* 24(208):101-109.
- + _____ 1942. Oude vrienden en nieuwe kennissen in den cultuurtuin. *Bergcultures* 16(6):134.
- D. 1901. See Anonymous 1901.
- DAFERT, F. W. 1899. *Erfahrungen über rationellen kaffeebau*. Berlin, Paul Parey. 60 p.
- DARLINGTON, C. D. 1932. *Chromosomes and plant breeding*. London, Macmillan Co. 112 p.
- DAVID, P. A. 1928. Introduced coffees lose resistance to the rust fungus Hemileia vastatrix Berkeley and Broome. *Philippine Agriculturist* 17(1):45-49.
- de Blij, C. H. See Blij, C. H. de.
- de Boer, H. J. See Boer, H. J. de.
- de Candolle, A. See Candolle, A. de.
- DEENEN, W. J. 1936. Bloei en bloei en bloeislagging van de robusta koffie op Sumatra's Westkust. Wageningen. 102 p.
- de Fluiter, H. J. See Fluiter, H. J. de.
- de Graaff, D. See Graaff, D. de.
- de Haan, H. R. M. See Haan, H. R. M. de.
- de Haan, I. See Haan, I. de.
- Delacroix, G. 1900. *Les maladies et les ennemis des caféiers*. 2d ed. Paris. 212 p.
- _____ 1911. *Maladies des plantes cultivées dans les pays chauds*. Paris. 595 p.
- de Light, N. M. See Light, N. M. de.
- DELLEN, A. J. W. van. 1886. De Liberia - koffie op Gemampier. *Ned.-Ind. Nijverheid Landbouw Tijdschrift* 33:324, 327, 332, 347.
- DELLEN, LAERNE C. F. van. 1885. *Brazil and Java; report of coffee culture in America, Asia and Africa to the H. E. the Minister of the Colonies*. London, W. H. Allen & Co. 637 p.
- de Munnick. See Munnick, de.
- de Stoppelaar, A. See Stoppelaar, A. de.
- de Sturler, W. L. See Sturler, W. L. de.

- de Vogel, C. J. See Vogel, C. J. de.
- de Vries, H. See Vries, H. de.
- de Wildeman, E. See Wildeman, E. de.
- DI FULVIO, A. 1939. World statistical situation of coffee. *International Review of Agriculture* 30(5):441S-457S.
- DINGER, H. 1934. Waarom verdient het bemestingsvraagstuk bij de koffiecultuur onze speciale aandacht. *Bergcultures* 8(27):631-640.
- Dinsdag. 1929. See Besoekische Landbouw Proefstation. 1929.
- DIVER, C. 1940. The problem of closely related species living in the same area. In Huxley, Julian. *The new systematics*. London, Oxford University Press. pp. 303-328.
- DOORN, J. F. van. 1937. Bodembedekking in den koffieaanplant. *Bergcultures* 11(25):903-910.
- DOORNBERG, G. D. 1930. Fermenteeren van koffie volgens de methode "Groenewege". *Bergcultures* 4(6):134-135.
- DRAAYER, L. 1937. De "Draayer" pulper. *Bergcultures* 11(15):1810-1812.
- du Bois, E. See Bois, E. du.
- du Pasquier, R. See Pasquier, R. du.
- DUARTE, C. 1930. Sur les teneurs en eau et en caféine des cafés des îles de S. Tomé et du Prince. *Brasil, Instituto Superior de Agronomia. Anais* 4. 10 p.
- DUBARD, M. 1906. Seconde note sur les caféiers sauvages de la Montagne d'Ambre. *Agriculture Pratique des Pays Chauds* 6(45):518-521.
- _____ 1908. Sur l'immunité du Coffea congensis var. Charlotti Pierre a l'Hemileia vastatrix. *Agricultura Tropicale* 8(90):363-364.
- DUSSERT, P. 1910. Note sur les caféiers résistants a l'Hemileia vastatrix et qui ont été introduits a la Réunion et a Madagascar. *Agriculture Pratique des Pays Chauds* 10(2):337-338.
- ELLIOTT, G. F. S. 1893. Economic plants of Sierra Leone. *Kew Bulletin* no. 79. 167 p.
- Encyclopedies van Nederlandsch-Indië. 1918. See Anonymous 1918.
- ENGLER, A. & PRANTL, K. A. E. 1897. Die natürlichen Pflanzenfamilien nebst ihren Gattungen und wichtigeren Arten insbesondere den Nutzpflanzen, unter Mitwirkung zahlreicher hervorragender Fachgelehrten. IV. Leipzig, W. Englemann. p. 104.
- FABER, F. C. von 1910. Een en ander over de biologie van de koffiebloem. *Teyssmannia* 21. pp. 556-577.
- _____ 1912. Morphologisch - physiologische undersøchungen an blüten von Coffea - arten. *Buitensorg. Jardin Botanique. Annales* 25(2me Ser.) 10(1):59-169.
- FAGERLIND, F. 1934. Beiträge zur kenntnis der systologie der Rubiaceen. *Hereditas* 19:223-232.

- + FAUCHERE, A. 1906. Culture pratique du caféier. Agriculture Pratique des Pays Chauds 6. pp. 451, 455, 458.
- _____ 1908. La culture pratique du caféier et préparation du café. Paris. 198 p.
- _____ 1910. Le 'Coffea congensis var. chalotti' á Madagascar. Journal d'Agriculture Tropicale 10(103):1-4.
- _____ 1919. La culture du caféier á Madagascar. Journal d'Agriculture Tropicale 19(159):267-268.
- _____ 1922. Guide pratique d'agriculture tropicale. II. Les grandes cultures. Paris Augustin Challamel. 468 p.
- FEILDEN, G. ST. CLAIR, COMP. 1940. Vegetative propagation of tropical and subtropical plantation crops. Great Britain. Imperial Bureau of Horticulture and Plantation Crops Technical Communication no. 13. 99 p. (Coffee, pp. 33-51).
- + FERNANDES, D. S. 1928. Nadere gegevens over de nieuwe bereidingswijze van onze Liberia - koffie. Mededeeling Landbouw Proefstation, Suriname. no. 4.
- _____ 1930. Recherches sur la préparation du café "Liberia" en Suriname. Anvers: Congres International 5me. Agriculture Tropicale. Rapport, 1930. pp. 647-650. (Also in Bulletin Agricole du Congo Belge 21(3):934-938. 1931.
- FERNIE, L. M. 1940. The rooting of softwood cuttings of Coffea arabica. East African Agricultural Journal 5(4):323-329.
- FERWERDA, F. P. 1932. Enten versus zaailingen bij koffie. Bergcultures 6(5):629-644.
- _____ 1933. Bloei en bloeislaging bij koffie. Bergcultures 7(11):306-312.
- _____ 1934. The vegetative propagation of coffee. Empire Journal of Experimental Agriculture 2(7):189-199.
- _____ 1934a. Conuga - koffie. Bergcultures 8(26):601-602.
- _____ 1935. Gegevens der voornamste zaaisels en cloonen verkregen uit de koffieselectie op Bangelan. Archief voor de Koffiecultuur 9(1):1-25.
- _____ 1935a. Information at a meeting of the Malang Landbouw Vereeniging. Bergcultures 9(19):432, 433.
- _____ 1935b. Het voorkomen van voosboon bij koffie en zijn samenhang met bevruchting en vruchtsetting. Bergcultures 9(22):500-509.
- _____ 1936. Enkele waarnemingen over de bestuiving van koffie. Archief voor de Koffiecultuur 10(1):32-41.
- _____ 1937. Gegevens over den ontwikkelingsduur der vrucht bij verschillende koffiesoorten. Bergcultures 11(7):198-203.
- _____ 1937a. Kiemkracht en levensduur van koffiestuifmeel. Archief voor de Koffiecultuur 11(2):135-150.
- _____ 1937b. Nadere gegevens over het optreden van onvolkomen ontwikkelde boonen bij koffie. Archief voor de Koffiecultuur 11(1):119-134.
- _____ 1941. Resultaten van eenige mengproeven met koffiecloonen op Bangelan. Bergcultures 15(18): 557-566.

- FESCA, M. 1904. Der Pflanzenbau in den Tropen und Subtropen I. Berlin, W. Süsserott. p. 210. (Susserotts Kolonialbibliothek. Bd. 7).
- FLUITER, H. J. de. 1935. Inleiding over de topsterfte - ziekte bij koffie. Bergcultures 9(41):1013, 1024.
- _____ 1936. Onderzoekingen omtrent de witte luizen van de koffie. Bergcultures 10(52): 1630-1639.
- _____ 1936a. Onderzoekingen en waarnemingen insake de witte luis in het jaar 1935. Bergcultures 10(25):772, 775; (26):847.
- + _____ 1936b. Over het verschijnsel der pseudogalvorming bij koffiewortels. Bergcultures 10(51):1612.
- _____ 1936c. Voorloopige mededeeling i. z. het onderzoek over een engerlingenplaag in de Java koffie. Bergcultures 10(12):374; (13):420, 424.
- + _____ 1937. Resultaten ver kregen bij het beplanten van met aaltjes besmette terreinen. Bergcultures 11(34):1226, 1227.
- _____ 1937a. Waarnemingen omtrent de witte luis bestrijding. Bergcultures 11(27):995-999.
- _____ 1939. Waarnemingen betreffende het bewaren van zaadkoffie. Bergcultures 13(43): 1506-1512.
- _____ 1939a. Het witte luis vraagstuk bij koffie. Bergcultures 13(23):760-766.
- _____ 1941. Onderzoekingen omtrent Pseudococcus citri (Risso, 1813) de dompolanluis van de koffie, en haar bestrijding. Archief voor de Koffiecultuur 15:1-119.
- _____ & MULHOLLAND, J. J. 1941. Gegevens verkregen bij het onderzoek naar de waardplanten van Tylenchus coffeae. Bergcultures 15:1588-1593.
- Frahm-Leliveld, J. A. See Leliveld, J. A.
- FRANCE. MINISTERE DE LA MARINE ET DES COLONIES. 1886. Les plantes utiles des Colonies Françaises, ouvrage publié sous la direction de J. L. de Lanessan. Paris. 990 p.
- FRANCO, C. M. 1939. Relation between chromosome number and stomata in Coffea. Botanical Gazette 100(4):817-827.
- FRANCOIS, E. 1931. La culture du caféier d'Arabie en Afrique Orientale. Revue de Botanique Appliquée et d'Agriculture Tropicale 11(114):77-83.
- _____ 1939. L'avenir de la culture des caféiers a Madagascar; état actuel de la question. Revue de Botanique Appliquée et d'Agriculture Tropicale 20(223):153-164.
- FRANSSSEN, C. J. H. 1932. De beteekenis van Apis indica als bloembestuivens insect. Bergcultures 6(52):1417-1423.
- FRIEDERICHS, K. 1923. Verslag van den entomoloog over het tijdvak Januari 1922-31 December 1922. Koffiebessenboek Fonds. Mededeeling no. 7. pp. 149-153.
- _____ 1924. Bionomische gegevens omtrent den koffiebessenboek. Koffiebessenboek Fonds. Mededeeling no. 11. pp. 261-286.
- _____ 1924a. In hoever bestaan er verschillen in de vatbaarheid der koffiesorten voor den koffiebessen boek? Koffiebessenboek Fonds. Mededeeling no. 11. pp. 315-354.
- _____ 1925. Handleiding voor de bestrijding van den koffiebessenboek. Archief voor de Koffiecultuur 1(2):108-118.
- FRITZ, A. 1935. Préparation du café par voie humide; étude de la fermentation. Agronomie Coloniale 24(206):41-47; (207):72-84.

- FROEHNER, A. 1897. Uebersicht über die Arten der Gattung Coffea. Berlin. Botanische Garten u. Museums. Notisblatt 1(7):230-235.
- _____ 1898. Die Gattung Coffea und ihre Arten. Leipzig. Systematik Pflanzengeschichte und Pflanzengeographie. Botanische Jahrbucher 25, pp. 233, 235, 251, 260, 263, 264, 268, 269.
- FRONTOU, G. 1928. La culture du caféier Arabica á Java. Bulletin Economische Indochine (n.s.) 31. pp. 61. 70.
- FRUWIRTH, C. 1923. Handbuch der landwirtschaftlichen pflanzensuchtung. V. Die Zuchtüing kolonialer Gewächse. Berlin, Paul Parey. 5 vols. p. 160.
- G. A. A. 1925. See Anonymous 1925.
- GALANG, F. G. 1928. Coffee culture. Philippine Agricultural Review 21:345-397.
- GANDRUP, J. 1922. Over boesboek in Loervak - koffie. Koffiebessenboesboek Fonds. Mededeeling no. 3. pp. 53-54.
- _____ 1923. Over de ligging van de endosperm plooi in koffievruchten. Vergard 3e. Vereen. Proefstation Person., 1922. pp. 97, 102.
- _____ 1930. Benaming van koffiesaad. Bergcultures 4(12):301.
- _____ 1934. Beschouwingen over periodiek verjongen van koffie - aanplantingen. Bergcultures 8(30):697-712.
- _____ 1934a. Een en ander over koffie - enten als plantmateriaal. Bergcultures 8(10): 220-226.
- _____ 1934b. Een proef over gangsirbestrijding. Bergcultures 8(25):579, 580.
- _____ 1934c. Kweckerij - selectie in de koffie - practijk. Bergcultures 8(22):501-502.
- + _____ 1935. Beschouwingen over cultuurproblemen bij koffie. Bergcultures 9(39):925-926.
- _____ 1935a. Eenige beschouwingen over de behandeling van schaduw in koffie - aanplantingen. Bergcultures 9(8):179-188.
- + _____ 1935b. Generative en vegetative vermenigvuldiging in de bergcultures. Bergcultures 9(17):377, 380.
- _____ 1935c. Verdere onderzoekingen over de ontkieming van rondboonsaad. Bergcultures 9(3):54-56.
- _____ 1936. Een korte omschrijving van plaksoogen en het maken van wortelenten. Bergcultures 10(36):1082-1084.
- _____ 1937. Wat hebben de laatste jaren ons geleerd over de koffiecultuur? Bergcultures 11(13):418-423.
- + _____ 1938. Een causerietje. Bergcultures 12(1):9, 12.
- + _____ 1939. Over de schadelijkheid van Salvia. Bergcultures 13(11):339.
- + _____ & SCHWEIZER, J. 1931. Java - koffie. Verslag, 1927, 1928, 1929. Besoekisch Proefstation Mededeeling no. 46. pp. 52, 53.

- GANDRUP, J. & SNOEP, W. 1935. Mededeeling van het Proefstation Midden - en Oost - Java over Koffiebloei enquetes gehouden door het Proefstation Midden - en Oost - Java. *Bergcultures* 9(29):641-645.
- GELINCK, A. M. 1942. Snoei van vruchtboomen en van de Robusta in het bijzonder. *Bergcultures* 16(5):106-114.
- * GENTIL, L. 1902. Bemerkungen über den botanischen Garten in Victoria (Kamerun). *Tropenpflanzer* 6:245-248.
- GERRETSEN, F. H. 1931. Bestrijding zwarte takkenboek. *Bergcultures* 5(39):1080-1083, 1087-1090.
- _____ 1935. Iets over de methodiek bij het verenten van koffie. *Bergcultures* 9(40):978-980.
- * GIESBERGER, G. 1937. Enkele ervaringen met de olfactometrische aroma - bepaling bij cacao en haar beteekenis voor onderzoekingen ter verbetering van de kwaliteit van aromatische cultuurproducten. Verslag 25 Vergard. Vereen. Proefstation Person., 1937. p. 170.
- GILBERT, S. M. 1938. Variability in yield of Coffea arabica. *East African Agricultural Journal* 4(2):131-139.
- _____ 1939. Selection within Coffea arabica in Tanganyika Territory. *East African Agricultural Journal* 4(4):249-253.
- GILBERT, W. W. 1940. Jesse Baker Norton, 1877-1938. *Journal of Heredity* 31(6):273-276.
- GOOT, P. van der. 1915. Over de biologie der gramang - mier (Plagiolepis longipes jerd.) Midden - Java. Salatiga Proefstation. Mededeeling no. 19. p. 52.
- + _____ 1916. De oeconomische beteekenis der gramang - mier. Midden - Java. Salatiga Proefstation. Mededeeling no. 22.
- * GORKUM, V. G. van. 1901. Catalogue des plantes économiques pour les colonies. *Koffiegids* 2:566, 568.
- GORTER, K. 1907. Beiträge zur kenntnis des kaffees. Ind. Neerland. Department of Agriculture Bulletin 14. 62 p.
- _____ 1907a. Koffie zonder coffeine. *Teysmannia* 18:239, 240.
- _____ 1908. Over het coffeine gehalte van eenige op Java gekweekte koffiesoorten. *Teysmannia* 19:774, 776, 778.
- _____ 1910. Over de wijze van enten in den koffieproeftuin Bangelan. *Teysmannia* 21. pp. 31-33.
- GORTMANS, C. G. 1928. Eenige aanteekeningen betreffende de koffiecultuur in de Toradja - landen (Celebes). *Landbouw* 4(3):171.
- Gouvernements - koffiecultuur. 1888-1889. See Anonymous 1888-1889.
- GRAAFF, D. de. 1941. Knopdifferentiatie en slaging van koffie - enten. *Bergcultures* 15(35):1192-1196.
- * GRAICHEN, H. I. 1900-1901. Eene maatschappij tot winning van saadkoffie. *Koffiegids* 2:37.
- * GRESHOFF, M. 1890. Olie in Liberia - koffiebloemen. *Teysmannia* 1:205.

- GRIST, D. H. 1936. An outline of Malayan Agriculture. Kuala Lumpur, S. S. & F. M. S. Department of Agriculture. Malayan Planting Manual no. 2. 378 p.
- GROENEWEGE, J. 1928. Over koffieverfermentatie. Archief voor de Koffiecultuur 2(2):133-145.
- HAAN, H. R. M. de. 1923. De bloembioologie van robusta - koffie. Malang Proefstation. Mededeeling no. 40. 97 p.
- _____ 1923a. Enkele morfologische mededeelingen over koffie. Verslag 3e Vergard. Vereen. Proefst. Person. 90 p.
- _____ 1923b. Het enten van koffie. Malang Proefstation. Mededeeling no. 41. pp. 4, 14, 18, 22.
- + _____ 1923c. Koffie selectie. Ned.-Ind. Landbouw Syndicaat Publicatie 15:147, 151.
- _____ 1923d. Overzicht der koffieliteratuur. Soerabaja, H. van Ingen. 58 p. (Malang. Proefstation. Mededeelingen, no. 39).
- HAAN, I. de. 1938. De Ceratophorum - bladziekte van jong Albizzia - planten. Archief voor de Theecultuur 12:303.
- HAGEN, J. 1917. Onze Koloniale landbouw. VII. De koffiecultuur. 2d ed. Haarlem, H. D. Tjeenk Willink & Sons. 90 p.
- + HAGENAAR, R. 1890. Java - koffie op Liberia - stam. Tijdschrift voor Land- en Tuinbouw en Boschcultuur in Nederlandsch - Oost - Indië, 5. p. 44.
- HALL, C. J. J. van. 1912. Gegevens over robusta en aanverwante koffiesoorten. Teysmannia 23(10-11):620-644; 740-756.
- _____ 1912-1917. Eerste, Tweede, Derde, verslags van de robusta - selectie, 1912, 1914, 1917. Midden - Java. Proefstation Salatiga. Mededeeling nos. 7, 15, 31.
- _____ 1921. Ziekten en plagen der cultuurgewassen in Nederlandsch - Indie in 1920. Buitenzorg. Instituut voor Plantenziekten. Mededeeling no. 46. 50 p.
- _____ 1938. Coffee selection in the Netherlands Indies. Amsterdam. Colonial Instituut Bulletin 1(2):135-143. (Also in Tropical Agriculture (Trinidad) 15(4):87-90. 1938).
- _____ & HELTEN, W. M. van. 1915. Een nieuwe dadap soort uit Venezuela ("Bocare anauco"). Buitenzorg. Cultuurtuin Mededeeling no. 3. 4 p.
- _____ & HELTEN, W. M. van. 1917. Overzicht der koffie - aanplantingen in den cultuurtuin. Buitenzorg. Cultuurtuin Mededeeling no. 7. 50 p.
- _____ & RUTGERS, A. A. L. 1922. Rapport over eenige proefnemingen met het middel van Davelaar op de ondernemingen Tambak - Kebonso en Melambong. Koffiebessenboek Fonds, Mededeeling no. 5. pp. 81-84.
- HALLAUER, E. R. 1923. Verslag van de proeven ter bestrijding der koffiebessenboek met de methode van Davelaar (Smeermethode). Midden - Java. Proefstation Salatiga. Mededeeling no. 38. pp. 1-41.
- + HAM, S. P. 1908. de grond - en boschpolitiek op Java. Tijdschrift. Binnenl. Bestuur, 35. p. 109.

HANAUSCK, T. H. 1895. Ueber symmetrische und polyembryonische samen von Coffea arabica L. Bericht der Deutschen Botanischen Gesellschaft (Berlin) 13. p. 73.

Handleiding 1873. See Anonymous 1873.

* HEIJDEN, M. V. 1899 - 1901. Brief dd. 18-1-1900. Koffiegids 1:1239.

* HELTEN, W. M. van. 1911. Uganda koffie. Teysmannia 22:715.

_____ 1913. De resultaten verkregen in den cultuurtuin met verschillende groene bemesters. Buitenzorg. Cultuurtuin Mededeeling no. 1. 19 p.

_____ 1915. Het enten van koffie. Buitenzorg. Cultuurtuin Mededeeling no. 4. 11 p.

_____ 1915a. Korte aanteekening over de vroeger beschreven groenbemesters. Buitenzorg. Cultuurtuin Mededeeling no. 2. 35 p.

* _____ 1918. Gids voor bezoekers van den cultuurtuin. Buitenzorg. Cultuurtuin Mededeeling no. II. pp. 43, 50, 51, 57.

_____ 1924. Practische ervaringen met verschillende soorten groenbemesters. Buitenzorg. Algemeen Proefstation Landbouw. Mededeeling no. 16. 71 p.

HENFLING, C. 1933. Bangelan 124-01 en Tylenchus similis. Bergcultures 7:1363-1365.

HENRY, 1908. Le cacao, le café et les cultures maraichères en Afrique Occidentale Française. Agriculture Pratiques des Pays Chauds 8. pp. 196, 203.

HERNDLHOFER, E. 1933. Menge und verteilung von protein, coffein, mono- und diaminozuren in der kaffeeplanze und deren monatliche schwankungen während einer vegetationsperiode. Tropenpflanzer 36(7):279.

* HEUBEL, G. A. 1938. Beknopt overzicht van de ondernemingscultures in het rayon Zuid - Sumatra gedurende 1937. Bergcultures 12(22):678, 685.

* _____ 1939. Beknopt overzicht van de ondernemingscultures in het rayon Zuid - Sumatra gedurende 1938. Bergcultures 13(23):768, 776.

* HEUSDEN, W. C. van. 1936. Beknopt overzicht van de meerjarige cultures in het rayon Zuid - Sumatra gedurende 1935. Bergcultures 10(22):688, 694.

HEWITT, R. 1872. Coffee, its history, cultivation and uses. New York, D. Appleton Co. 102 p.

HEYN, A. N. J. 1936. Cytologische onderzoekingen aan enkele tropische cultuurgewassen en de betekenis van dergelijke onderzoekingen voor de plantenveredeling. Landbouw 12(1):10-42.

_____ 1938. Du nombre de chromosomes chez quelques végétaux en culture aux Indes Néerlandaises (Coffea, ceiba, oryza, derris et palaquin). Buitenzorg. Jardin Botanique. Annales 48. pp. 103-120.

* HEYTING, J. 1887. Handleiding voor de Gouvernements koffiecultuur op Java. Batavia. p. 37.

* HIDMA, TH. 1934. Het raadsel van de achteruitgang der Java - koffiecultuur. Java.

* HIERN, W. 1876. On the African species of the genus Coffea. Linnean Society. Transactions (Second Series) 1. pp. 169, 172.

Highland coffee of Sierra Leone. 1896. See Stennekes, L. 1898.

HILLE RIS LAMBERS, M. 1927. Boekbespreking. Bergcultures 2(12):339-340.

- HILLE RIS LAMBERS, M. 1928. Over verschillende "Robusta" typen. *Bergcultures* 2(51):1530.
- + _____ 1929. Verslag over de werkzaam - heden van het Proefstation Malang in het jaar 1928. Malang. Proefstation Mededeeling no. 69. pp. 24, 28, 31, 36, 78.
- _____ 1930. Historical review of the coffee selection in Java. Pacific Congress, 4th. Java, 1929. pp. 191-201.
- + _____ 1931. Note by, on the susceptibility of robustoid kinds of coffee. In Bally, W. Handboek voor de koffiecultuur. I. De ziekten van de Koffie. Amsterdam, J. H. de Bussey, p. 135.
- _____ 1931a. De selectie van koffie; een ander over de resultaten op Soember Asin. *Bergcultures* 5(25):684-695.
- _____ 1931b. Vijfde verslag van de Robusta - selectie op Banaran. Archief voor de Koffie-cultuur 4(3):101-110.
- _____ 1932. Vijf jaar selectiewerk op Soember Asin, September 1926 - October 1931. Archief voor de Koffiecultuur 6(1):1-42.
- _____ 1933. Gegevens over koffiekruisingen op Soember Asin. *Bergcultures* 7(52):1409-1416.
- _____ 1933a. Nieuwe gegevens over de koffieselectie in de Soember Asin nummers. *Bergcultures* 7(21):687-598.
- _____ 1934. Over kunstmatige kruisbestuiving van koffietuinen. *Bergcultures* 8(37):880-884.
- _____ 1935. Eenige mededeelingen over den huidige stand van de koffieselectie. *Bergcultures* 9(25):557-563.
- _____ 1935a. Kapakata - koffie. Archief voor de Koffiecultuur 9(3):105-115.
- + _____ 1935b. Kepelans also entrijs. *Bergcultures* 9(52):1457.
- _____ 1935c. Het verband tusschen de ontwikkeling van takenten en het gebruikte entrijs. *Bergcultures* 9(16):363-366.
- _____ 1936. Gegevens over Conuga. *Bergcultures* 10(19):596-597.
- _____ 1936a. Koffiekruisingen als plantmateriaal. *Bergcultures* 10(32):974-986.
- _____ 1937. Bestuivingsmogelijkheden bij koffie. *Bergcultures* 11(22):791-800.
- _____ 1937a. Ontwikkelingswegen voor de koffieselectie. *Bergcultures* 11(27):985-994.
- _____ 1938. Het onderkennen van koffiecloonen. Archief voor Koffiecultuur 12(3):165-189.
- + _____ 1938a. Vragenbus. *Bergcultures* 12(37):1274-1277.
- _____ 1939. Eenige waarnemingen over de ontwikkeling van den takent bij gebruik van verschillend entrijs. Archief voor de Koffiecultuur 13(2):70-84.
- _____ 1939a. Indrukken van de koffiecultuur in Oost - en Midden - Afrika. *Bergcultures* 13(52):1800-1810.
- _____ 1941. Koffieselectie en koffie - plantmateriaal. *Bergcultures* 15(45):1522-1532.
- HIRSCHFELDT, F. 1930. Eenige gegevens over de koffie in Angola. *Indische Mercur* 53(39):851-852.

- HCEDT, T. G. E. 1924. De stoomladder. Koffiebessenboek Fonds, Mededeeling no. 10. pp. 248-258.
- _____ 1928. Mededeeling over het boeboekvraagstuk in Zuid - Sumatra. Archief voor de Koffiecultuur 2(3):147-156.
- _____ 1929. Eenige voornamen verschilputen bij de koffiecultuur in Oost - Java en in Zuid - Sumatra. Bergcultures 3(35):887-900.
- + _____ 1930. Indische bergcultuur ondernemingen voornamelijk in Zuid - Sumatra, gegevens en beschouwingen. p. 207.
- _____ 1932. Aanteekeningen over koffie - snoei. Archief voor de Koffiecultuur 6(2):57-86.
- _____ 1934. Zaadloze lamtoro. Bergcultures 8(51):1210.
- + HOEFFER, J. J. C. 1887. Koffiebladziekte. Indische Mercur 10. pp. 459-460.
- HOLLAND, T. H. 1931. The green manuring of tea, coffee and cacao. Tropical Agriculturist (Ceylon) 77(4):197-204.
- + HOLLE, K. F. 1879. Diversen. In De Vriend van den Javaanschen Landman 7. p. 3.
- HOMEYER, H. 1932. Zur zytologie der Rubiaceen (Vorläuf: M tt.). Planta 18(3):640.
- + Ten HONES, J. E. 1908. De intensieve cultuur bij de koffie in vergelijking met het zg. Djuwoel-systeem. Verslag 9de Congres, Algemeen Suidicaat Koffiecultuur e.a. Bergcultures in Ned.-Ind., Soerabaja, 1907. Malang. pp. 651-668.
- + HONING, J. A. 1916-1918, 1928-1929. Een studiereis in Nederlandsch - Oost - Indië. Verslag Fonds Landbouw Export Bureau.
- + HOOFF, N. W. S. van. 1903-1904. Iets over de Coffea robusta op de Pondoklanden. Cultuurgids 5. p. 272.
- + HORTICOLE COLONIALE. (n.d.) Plantes pour les colonies; catalogue de "l'Horticole Coloniale." Bruxelles. p. 66.
- HOUK, W. G. 1939. Nomenclatura dos cafeeiros; lista de referencias e bibliografia. Sao Paulo, Brasil, Instituto Agronomico de Campinas, Boletim Técnico no. 63. 49 p.
- HUDSON, P. S. 1937. Genetics in its application to plant breeding. Biological Review 12:285-319.
- HUITEMA, W. K. 1933. De zaadloze lamtoro. Bergcultures 7(24):680-683.
- + _____ 1935. De bevolkingskoffiecultuur op Sumatra, met een inleiding tot hare geschiedenis op Java en Sumatra. Proefschrift Landbouw Hoogeschool. Wageningen. pp. 33-214.
- HULL, E. C. P. 1877. Coffee planting in Southern India and Ceylon. London. 324 p.
- Hulpgewassen. 1939. See Anonymous 1939.
- Hybride iets over de Liberia met Java - Koffie. 1893. See Anonymous 1893.
- + INDISCHE MERCUUR. 1888-1904. (No titles). 1888, p. 563; 1890, p. 73; 1892, pp. 268, 481, 581; 1893, pp. 275, 327, 418, 562; 1897, p. 156, 691; 1898, pp. 254, 273, 552; 1899, pp. 287, 667, 782; 1904, p. 69.

- INDONESIE. CENTRALE PROEFSTATIONS VEREENIGING. 1941. Vraagbaak voor de koffiecultuur en de koffiebereiding. Bogor.
- INSTITUT INTERNATIONAL D'AGRICULTURE. 1929. Notes bibliographiques sur le café (1924-1929) présentées au Congrès International du Café, Séville, 26th. September 1929. Rome. 35 p.
- INEAC. 1939. See Congo Belge. Institut National pour l'Etude Agronomique. 1939.
- ISASCA, A. J. V. 1941. Vijfentwintig jaar "Robusta". Bergcultures 15(40):1364-1372.
- Jaarboeken. 1901-1928. See Nederlandsch - Indie. Laboratorium Onderzoek. 1901-1928.
- Jaarverslag. 1891-1896. See Soekaboemische en Bataviaasche Landbouwvereening. 1891-1896.
- Jaarverslag 1901-1928. See Nederlandsche - Indie. Laboratorium Onderzoeken. Department Landbouw. 1901-1928.
- * JACOB, H. S. 1899. Instandhouding der koffiecultuur met hulp der regeering. Indische Mercur 22(50):869, 870.
- + _____ 1899-1900. To be or not to be. Koffiegids 1:488.
- JACOB, J. C. s. 1934. Het takkenboekvraagstuk. Bergcultures 8(44):1049.
- * _____ 1936. Ervaringen met watercultures van koffie. Vergard. Vereen. Proefstation Person., Verslag 16. p. 94-107.
- _____ 1936a. Voorloopige mededeeling over watercultures met koffie. Bergcultures 10(52):1645-1651.
- _____ 1938. Korte mededeeling over wortelconcurrentie bij koffie in watercultuur. Bergcultures 12(40):1366-1370.
- _____ 1938a. Resultaten van zaailingtoetstuinten in Besoeki. Archief voor de Koffiecultuur 12(2):56-108.
- _____ 1938b. Voedigsfysiologische onderzoekingen bij Coffea arabica L. I. Archief voor de Koffiecultuur 12(1):1-48.
- + _____ & HILLE RIS LAMBERS, M. 1938. De huidige stand van het veredelingswerk bij koffie. Vergard. Vereen. Proefstation Person. Verslag 26. pp. 38, 39, 40, 41, 43, 44.
- + _____ & VEEN, R. van der. 1939. Bodemverzorging en bodemzorgen in de koffie. Bergcultures 13(6):176.
- JANSSEN, P. 1930. Le café Robusta dans l'Angola. Bruxelles, Impr. Industrielle et Financiere. 117 p.
- JORGENSEN, C. A. 1928. The experimental formation of heteroploid plants in the genus Solanum. Journal of Genetics 19:133-211.
- JOTAPEN, J. 1915. The cultivation and preparation of coffee for the market. Aberdeen. 102 p.
- JURION, F. 1936. Resistance au climat des caféiers arabica du type brun. Etude préliminaire. La brûlure des caféiers. Institut National Pour l'Etude Agronomique du Congo Belge (INEAC) Serie Scientifique no. 6. 19 p.

- * **KALFF, S.** 1927. Uit de kinderjaren van de koffiecultuur. Indische Culturen 12. pp. 141-142.
- KALSHOVEN, L. G. E.** 1938. Invloed van insecten op de Kwaliteit en verhandelbaarheid van Indische Landbouwproducten. Landbouw 14(2):70-117.
- * **KAMERLING, Z.** 1914. De groote problemen der Koffiecultuur. Wageningen.
- + _____ 1918. Koffie. In Gorkom, K. W. van. Oost - Indische cultures. 2d ed. 1918. pp. 179, 218.
- * **KARSEN, H. TH.** 1893. Koffieblad - thee. Indische Mercur 16(42):628.
- KEDIRISCHE. LANDBOUW VEREENIGING.** 1900-1901. Extract - notulen v. d. Vergard. Koffiegids 2:917.
- * **KELLER, S.** 1903-1904. De bereiding van Liberia - koffie met toepassing van kokend water. Cultuurgids 5. p. 989.
- KEUCHENUIS, A. A. M. N.** 1927. Over de ontwikkeling van leguminosen wortels. Bergcultures 2(16):461-465.
- _____ 1936. De ondernemingscultures ter Sumatra's Westkust. Bergcultures 10(1):6-15.
- + _____ 1936a. Overzicht van de meerjarige cultures in het rayon West - Sumatra gedurende 1935. Bergcultures 10(14):448.
- _____ 1937. Grondonderzoek, kalk en koffieproducties ter Sumatra's Westkust. Bergcultures 11(10):307-311.
- + _____ 1938. Overzicht van de onvernemingscultures in het rayon West - Sumatra gedurende 1937. Bergcultures 12(10):268, 270, 311.
- + **KEUCHENUIS, P. E.** 1914. Enkele beschouwingen over de schildluizen van de koffie. Besoekisch Proefstation Mededeeling no. 8. pp. 9, 17.
- + **KIEVITS, J. H.** 1891. Het kweeken van Liberia - koffie. Teysmannia 2. pp. 89-93.
- * **KISSING, A. P. A.** 1900-1901. Nadere toelichting op het artikel "Koffie in Palembang". Koffiegids 2. p. 106.
- * **KIVU. MULUNGU STATION. SERVICE PHYTOPATHOLOGIQUE ET AGRICOLE.** 1933. Sur un peuplement de caféiers spontanés au Kivu. Bruxelles. Revue Agrolgique et Botanique du Kivu no. 2. p. 17.
- * **KLUVERS,** 1903. Practische en financieele beschouwingen over eenige bergcultures. Cultuurgids 5. pp. 564, 568.
- KNAUS, C.** 1929. De koffiebereiding in Ned.-Indië; resultaten en beschouwingen naar aanleiding van een in 1928 gehouden enquête. Archief voor de Koffiecultuur 3(2):27-111.
- _____ 1929a. Een koffiebereidings - installatie voor kleine ondernemingen. Bergcultures 3(51):1295-1297.
- _____ 1930. Cafféine, asch - en extractgehalte van Robusta - koffie. Archief voor de Koffiecultuur 4(1):20-28.
- _____ 1933. Standaardiseering van de koffiebereiding. Bergcultures 7(25):711-712.
- _____ 1934. Eenige praktijkresultaten met den "Torendroger" en den "Harkencarriëdroger". Bergcultures 8(11)-241-242.

- + KNAUS, C. 1935. Koffie met "dull roast" (doffe brand). *Bergcultures* 9(33):744.
- + _____ 1936. Bereiding. *Bergcultures* 10(30):925.
- + KNEPPER, J. 1898. De tegenwoordige stand van het enten van Java - op Liberia - koffie. Verslag van het iste K^uffie Congres in Nederlandisch - Indie, gehouden te Malang op 12, 13 en 14 October 1898. p. 102.
- KOCH, L. & WEBER, F. W. 1928. Proefsnitten en analyses van 28 verschillende groene bemesters. Buitensorg. Algemeen Proefstation Landbouw. Mededeeling no. 27. 85 p.
- Koffier - rooikeur. 1936. See Anonymous 1936.
- KONINGSBERGER, J. C. 1897. De dierlijke vijanden der kovviecultuur op Java. Batavia. s' Lands Plantentuin. Mededeeling no. 20.
- + _____ 1902-1903. Eenige opmerkingen over de fauna der koffie - ondernemingen en hunne omgeving. *Cultuurgids* 4. p. 538.
- _____ & ZIMMERMAN, A. 1901. Der dierlijke vijanden der koffiecultuur op Java II. Batavia. s' Lands Plantentuin. Mededeeling no. 44. 125 p.
- + KOOLHAAS, D. R. 1938. Pre - advies 3e gewijzigd ontwerpverordeningkoffie. Bogor, Chemical Laboratory. (In manuscript, not published).
- + KOORDERS, S. H. 1894. Over de samenstelling van eenige bosschen in de residentie Madioen. *Tijdschrift voor Nijverheid en Landbouw in Nederlandsch - Indie*, vol. 48, p. 205.
- + _____ 1899. De koffiesoorten der boschboomflora van Java. *Teymannia* 10. p. 491.
- + _____ 1901-1902. Botanisch - systematische opmerkingen over voor komen en beteekenis van drie - en meersadige Koffievruchten. *Cultuurgids* 3. p. 357.
- + KOSTLAN, A. 1913. Die Landwirtschaft in Abessinien. *Tropenpflanzer* 17(4):181, 235.
- KRAMERS, J. G. 1898. Waarnemingen en beschouwingen naar aanleiding van eene reis in de koffie. Batavia. 's Lands Plantentuin Mededeeling no. 24. pp. 51, 89, 90, 91.
- _____ 1899. De met enten in de koffie tot nu toe verkregen uitkomsten en de vooruitsichten daarvan. *Teymannia* 10(11):535-568.
- + _____ 1899a. Verslag omtrent de proeftuinen. Batavia. 's Lands Plantentuin. Mededeeling no. 32. pp. 79, 80, 82, 96.
- + _____ 1900. Tweede verslag omtrent de proeftuinen. Batavia. 's Lands Plantentuin. Mededeeling no. 38. pp. 36, 37, 40, 75, 76.
- + _____ 1901-1902. De koffiëproeftuin van 's Lands Plantentuin. *Cultuurgids* 3. p. 546-562.
- + _____ 1902-1903. Opmerkingen over koffie op Sumatra en in Java. *Cultuurgids* 4. p. 488, 503.
- + _____ 1904. Vierde verslag omtrent de proeftuinen. Batavia. 's Lands Plantentuin. Mededeeling no. 75. pp. 62, 66, 71.
- KROON, A. H. J. 1928. Landbouw in Palembang. Bandoeng. *Algemeen Landbouw - weekblad voor Ned.-Ind.* 13(2):36.
- KRUG, C. A. 1934. Beitrag sur cytologie des genus Coffea. *Der Züchter* 6(6):166-168.

- KRUG, C. A. 1935. Hybridisation of coffee; a preliminary study of flowering habits, and of methods of crossing. *Journal of Heredity* 26(8):325-330.
- _____ 1936. Estudos citológicos em Coffea. II. Sao Paulo, Brasil, Instituto Agronómico de Campinas, Boletim Técnico no. 22. 6 p.
- _____ 1937. Cytological observations in Coffea. III. *Journal of Genetics* 34(3):399-414.
- _____ 1939. The genetics of Coffea. I. The inheritance of a dwarf type, nana. *Journal of Genetics* 37(1):41-50.
- _____ 1945. Plant breeding, genetics and cytology in Latin America. In Verdoorn, Frans. *Plants and plant science in Latin America*. Waltham, Mass., Chronica Botanica Co. pp. 243-258.
- _____ & CARVALHO, A. 1939. Genetical proof of the existence of coffee endosperm. *Nature (London)* 144(3646):515.
- _____ & MENDES, A. J. T. 1941. Observacoes citológicas em Coffea. IV. *Bragantia* 1(6): 467-482.
- _____ & MENDES, J. E. T. & CARVALHO, A. 1939. Taxonomia de Coffea arabica L.; descricao das variedades e formas encontradas no Estado de Sao Paulo. Sao Paulo, Brasil, Instituto Agronómico de Campinas, Boletim Técnico no. 62. 57 p., 58 plantas.
- KUNEMAN, J. 1890. De gouvernementen koffiecultuur op Java. 's Grafenbage. 201 p.
- KUNEMAN, J. H. 1939. Eenige practijkmededeelingen over het laanverband. *Bergcultures* 13(15):460-465.
- * LAER, A. van. 1904-1905. De tegenwoordige stand van het koffie - enten. *Cultuurgids* 6. pp. 96-98, 102.
- LAGERWERFF, J. M. 1903-1904. Over den groei der Coffea robusta op den Kloet. *Cultuurgids* 5. p. 26.
- LALIERE, A. 1909. Le café dans l'Etat de Saint Paul (Brésil). Paris, O. Forst. 417 p.
- LAMMERS, R. P. 1940. Een en ander over nieuwe lamtorovormen. *Bergcultures* 14(37):1168-1171.
- LANDBOUWEEKBLAD. 1916. (No title) p. 16.
- Lanessan, J. L. de. 1886. See France. *Ministere de la Marine et des Colonies*. 1886.
- LANGE, R. 1897. Waarnemingen bij het pellen van verschillende Liberia - koffie - oogsten. *Indische Mercur* 20(5):51.
- LANZING, P. G. A. 1907. Hemileia vastatrix op de Liberia - vrucht. *Cultuurgids* 8. p. 195.
- LEBRUN, J. 1941. Recherches morphologiques et systematiques sur les caféiers du Congoⁿ. Bruxelles, Institut Royal Colonial Belge, *Memoires (Collection in - 8°)* 11(3):1-183.
- LE COINTE, P. 1922. L'Amazonie brésilienne. Paris, A. Challamel. 2 vols. p. 195.
- LE COMTE, H. 1899. Le café, culture, manipulation. Paris, Carré. col. 6, 342 p.
- LE CONGE, H. 1934. Koffie. *Bergcultures* 8(28):653-658.

- LEDREUX, A. 1932. La culture des caféiers a Madagascar. *Agronomie Coloniale* 2(21):121-136.
- _____ 1933. L'ombrage des caféiers a Madagascar. Gouvernement Général de Madagascar et Dépendances, *Bulletin Economique Mensuel (Nouvelle Série)* no. 79. pp. 73-76.
- LEEFMANS, S. 1923. De koffiebessenboek. I. Levenswijze en oecologie. Mededeeling Instituut Plantenziekten no. 57. 97 p.
- LEEMBRUGGEN, W. C. 1901. Hoe een Liberia - koffie - pulper ontstond. *Indische Mercur* 24(10):167.
- LEIJSSIUS, H. TH. 1901. In Malangsche Vereeniging van koffieplanters. *Indische Mercur* 24(26): 496.
- LELIVELD, J. A. 1938. De cytologie als hulpmiddel bij de selectie. *Bergcultures* 12(26):847-854.
- + _____ 1938a. Ontwikkeling en doelstelling der cytogenetica. *Vergard. Vereen. Proefstation Person.*, 26. pp. 16, 25, 26.
- _____ 1938b. Vruchtsetting bij koffie. *Archief voor de Koffiecultuur* 12(3):127-164.
- _____ 1939. Cytologische gegevens betreffende eenige cloonen van Coffea "robusta". *Archief voor de Koffiecultuur* 13(1):1-26.
- _____ 1940. Nieuwe gezichtspunten voor het selectie - onderzoek bij soorten - kruisingen van koffie naar aanleiding van cytologische gegevens. *Bergcultures* 14(12):370-386.
- _____ 1940a. Ontstaan en voorkomen van rondboon en voosboon bij koffie. *Bergcultures* 14(43):1358-1362.
- + LENNEP, H. H. T. van. 1899-1900. Chairman's speech in Dutch at a Kediri planters' meeting, 8 July, 1899. *Koffiegids* 1. p. 532, 533.
- + _____ 1900-1901. Achteruitgang der koffie - productie in verband met zaadkeuze. *Koffiegids* 2. p. 31, 32.
- + _____ 1901-1902. Kan men resultaten verwachten van geïmporteerd koffiezaad? *Cultuurgids* 3. p. 640.
- + _____ 1905. Eenige mededeelingen over de Coffea robusta. *Cultuurgids* 7. p. 254.
- + _____ 1907. Mededeelingen omtrent de Coffea robusta. Verslag 9de Congres Alg. Synd. Koffiecultuur e.a. *Bergcultures in Ned.-Ind. Soerabaja*, December 1907. pp. 683, 695, 698, 704.
- LENOIR, H. 1932. Over de werkwijze in de koffie op de onderneming silosanen. *Bergcultures* 6(45):1208-1210, 1212, 1213.
- LEPLAE, E. 1936. Les plantations de café au Congo Belge; Leur histoire (1881-1935), leur importance actuelle. Bruxelles. Institut Royal Colonial Belge. *Mémoires* 3. 248 p.
- LEZER, E. 1937. Het afsterven van reeds geslaagde koffie - enten. *Bergcultures* 11(48):1709.
- Liberia koffiepulper "Lyon" 1897. See Anonymous 1897.
- LIGT, N. M. de. 1931. Hoe groot is het verlies aan koffie door de bessenboek veroorzaakt? *Bergcultures* 5(5):126-130; (6):143-147; (7):171-179.
- _____ 1935. De koffiebereiding. *Bergcultures* 9(47):1259-1270.

- LIGT, N. M. de. 1936. Coffea arabica als onderstam. Bergcultures 10(5):154-156.
- _____ 1936a. Plantverband - suggesties. Bergcultures 10(1):16-23.
- _____ 1936b. Het verloop van robusta - oogsten in verband met taxatie en bereiding. Bergcultures 10(3):72, 74, 82, 83.
- _____ 1937. Composteeren. Bergcultures 11(49):1740-1748.
- _____ 1937a. Ontginning met bodembescherming. Bergcultures 11(50):1766-1775.
- _____ 1938. Conuga - ervaringen. Bergcultures 12(29):972-975.
- _____ 1939. Conuga - koffie. Bergcultures 13(22):726-732.
- * LISNET, C. L. L. 1918. Antwoord in "vragenbus". Bendoeng. Algemeen Landbouw Weekblad voor Ned.-Ind. 2(46):831.
- LOCK, C. G. W. 1888. Coffee, its culture and commerce in all countries. London. 264 p.
- * LOTSY, P. 1926. Evolution in Lichte der Bastardierung betrachtet. Haag. p. 445.
- LUCHTMEIJER, H. 1940. Bijdrage tot het snoei - probleem bij Hoogproduceerende koffiëplanten. Bergcultures 14(11):358.
- McCLELLAND, T. B. 1924. Coffee varieties in Porto Rico. Puerto Rico Agricultural Experiment Station (Mayagüez) Bulletin no. 30. 27 p.
- McDONALD, J. A. ED. 1937. Coffee in Kenya. Nairobi, Government Printer. 210 p.
- McDONALD, J. H. 1930. Coffee growing; with special reference to East Africa. London, East Africa Ltd. 205 p.
- * MACGILLAVRY, H. D. 1898-1899. Nota der monsters Liberia - koffie van Djati Roenggo. Koffie-gids 1. p. 45.
- + _____ 1903-1904. De Coffea robusta op Djati Roenggo in Midden - Java. Cultuurgids 5. p. 753.
- * MAANEN, G. W. F. van. 1901. Welke is de beste koffie - pulper? Indische Mercur 24(4):62.
- MAAS, F. G. J. A. & BOEDIJN, K. B. 1927. Desinfectie van door besenboeboek (Stephanoderes hampei Ferr.) aangetast koffiëzaad. Archief voor de Koffiëcultuur 1(6):233-248.
- MAITLAND, T. D. 1926. Coffea robusta in Uganda. Uganda Department of Agriculture Circular no. 14. 12 p.
- MALANGSCHE LANDBOUW VEREENIGING. 1907. Coffea excelsa, voorkomende in Fransch Congo. Cultuur-gids 8:134-135.
- + _____ 1934. Notulen van de Algemeene Vergadering. Bergcultures 8(43):618, 1016, 1018, 1021.
- MALLAMAIRE, A. 1935. La désinfection des semences de caféiers par la chloropicrine. Agronomie Coloniale 24(213):70-79.
- Manuel pratique... 1908 See Bruxelles. Ministere des Colonies. 1908.
- MARGGRAFF, R. 1934. De koffiëcultuur in Britisch - Zuid - Indië. Bergcultures 8(42):988-996.

- MARGGRAFF, R. 1935. Gegevens over de warde van Kent's koffie. *Bergcultures* 9(8):169-171.
- + _____ 1938. De gevolgen van de wijziging der Braziliaansche koffiepolitiek. *Bergcultures* 12(12):348.
- Marshall H. Ward. See Ward, Marshall H.
- MARTIN, F. 1938. Le caféier; principes techniques et économiques de la culture de cette plante. Paris.
- + MAURENBRECHER, L. L. A. 1900-1901. Resultaten eener proefneming met hybride - koffie (enten en zaailingen van klein - Getas) in West Java. *Koffiegids*. 2:571-577.
- MAXWELL, J. 1928. The Gold Coast handbook. London, Crown Agents. p. 95.
- MAYNE, W. W. 1936. Annual report of the Coffee Scientific Officer 1935-36. *Mysore Coffee Experiment Station Bulletin*, no. 14. 21 p.
- _____ 1939. The possibilities of vegetative propagation of coffee. *East African Agricultural Journal* 5(3):186-189.
- + _____ 1939-1940. Annual report of the Coffee Scientific Officer, 1939-1940. *Mysore Coffee Experiment Station*.
- _____ 1940-1941. Annual report of the Coffee Scientific Officer, 1940-1941. *Mysore Coffee Experiment Station Bulletin* no. 23. 17 p.
- MENDES, A. J. T. 1938. Morfologia dos cromosomios de Coffea excelsa Sao Paulo, Brasil, Instituto Agronómico de Campinas, *Boletim Técnico* no. 56. 10 p.
- _____ 1938a. Os cromosomios das Rubiáceas. Sao Paulo, Brasil. Instituto Agronómico de Campinas, *Boletim Técnico* no. 55. 11 p.
- _____ 1939. Duplicacao do número de cromosomios em café, algadao e fumo, pela acao da colchicina. Sao Paulo, Brasil, Instituto Agronómico de Campinas, *Boletim Técnico* no. 57. 21 p. (Cited in *Revue de Botanique Appliquée d'Agriculture* 19:382. 1939).
- _____ & BACCHI, O. 1940. Observacoes citológicas em Coffea. V. Uma variedade haploide ("di - haploide") de Coffea arabica L. Sao Paulo, Brasil, Instituto Agronómico de Campinas, *Boletim Técnico* no. 77. 26 p.
- MENDES, J. E. T. 1939. Ensaio de variedades de cafeeiros. Sao Paulo, Brasil, Instituto Agronómico de Campinas, *Boletim Técnico* no. 65. pp. 1-36.
- _____ 1940. Adubacao verde para cafezais. Instituto de Café do Estado de Sao Paulo, Brasil. *Revista* 26(158):410-413, 415-418.
- _____ & KRUG, C. A. 1938. O cafeeiro e sua cultura; pesquisas e trabalhos experimentais em andamento. Sao Paulo, Brasil, Instituto Agronómico de Campinas, *Boletim Technico* no. 54. 37 p.
- MENDIOLA, N. B. 1928. A report on an agricultural investigation trip to Java, Federated Malay States, and Borneo. *Philippine Agriculturist* 17:3-23.
- _____ 1931. The Kawisari B coffee introduced in the College of Agriculture. *Philippine Agriculturist* 20(2):101-111.
- MEULEN, A. van der. 1938. Voorloopige mededeeling over het tijdstip van den bloemaanleg bij koffie. *Bergcultures* 12(14):416.

- MEULEN, A. van der. 1939. Over den bouw en de periodieke ontwikkeling der bloemknoppen bij koffie - soorten. Amsterdam, N. V. Noord - Hollandische Uitgevers Maatschappij. 127 p.
- MEYER, W. H. 1939. Beschouwingen over koffie - houtgradities, entrijskeuze en entrijsvermeerdering op ground van practijkwaarnemingen. Archief voor de Koffiecultuur 13(2):51-70.
- * MEYLINK, J. R. 1917. Robusta enquete. Bandoeng. Algemeen Landbouw Weekblad voor de Ned.-Ind. no. 1 p. 8.
- * MINDERHOUD, A. 1931. Onderzoekingen over het gedrag der honingbij als; bestuivend insect. Groningen, Landbouwkundig Tijdschrift 43:32, 53.
- * MINY, M. 1927. Culture du caféier au Congo Belge. Rapport International Conference Tropical Products 7th. International Rubber Exhibition, Paris, 1927. pp. 148, 155.
- MOHR, E. C. J. 1938. De bodem der tropen in het algemeen, en die van Nederlandsch-Indie in het bijzonder. Meded. Koninklijke Vereeniging Koloniaal Instituut. Afdeling Handelsmuseum, Amsterdam 31(2):573-816.
- * MONDT, H. J. 1934. Gargoyle mobilgrease Nr. 2. Bergcultures 8(26):606.
- * _____ 1935. Demonstration of a double rooted Robusta tree (illustr.) in a meeting of the Malang Landbouw Vereen. Bergcultures 9(19):424, 430.
- * MOORE, S. 1911-1912. A contribution to our knowledge of the flora of Gazaland. Linnean Society. Journal (Botany) 40:77, 95.
- MORREN, F. W. 1894. Cultuur, bereiding en handel van Liberia koffie. Amsterdam. 36 p.
- _____ 1896. *Werkzaamheden op eene koffiëonderneming; handleiding voor opzichters bij de koffiëcultuur.* Amsterdam. 266 p.
- _____ 1899. Koffiëcultuur in Guatemala, met aantekeningen betreffende de overige cultures de mijnen en den economischen toestand van deze republiek. Amsterdam. 142 p.
- MORRIS, D. 1879. Reports upon experiments connected with the coffee leaf disease. Colombo, Sessional Paper 12.
- _____ 1881. Notes on Liberian coffee. Jamaica. Department of Public Gardens and Plantations. 14 p.
- * MULDER, D. 1896. Liberia - koffie - pulper. Indische Mercur 19(37):577.
- MULDER, H. H. 1937. Hoe beïnvloeden wij het slagingspercentage van onze koffie - enten. Bergcultures 11(38):1371-1372.
- * MULLER, C. R. 1932. Eenige gegevens over Paria (Momordica Charantia) tusschen koffie - aanplant. Bandoeng, Algemeen Landbouw Weekblad voor Ned.-Ind. 16(52):1375.
- MULLER, H. R. A. 1929. Voorloopige mededeling over een schimmel, geïsoleerd uit instervende koffie boomen in Zuid - Sumatra. Archief voor de Koffiecultuur 3(3):167-181.
- _____ 1930. Verband tusschen den zuurgraad van den grond en het optreden van topsterfte. Archief voor de Koffiecultuur 4(1):29-31.
- * _____ 1935. Verslag over de topsterfteproeven op de onderneming Ngrankak - Pawon, 1932-1933. Archief voor de Koffiecultuur 9(2):38, 45.
- _____ 1936. Topsterfte van koffie. Archief voor de Koffiecultuur 10(4):279-349.

- * MUNNICK, DE. 1863. Handleiding voor de kultuur en de bereiding der koffy op Java. Batavia. (Older edition 1843 also referred to).
- * MUNTZING, A. 1935-1936. The evolutionary significance of autopolyploidy. *Hereditas* 21:263, 282-283.
- * NEDERLANDSCH - INDIE. LABORATORIUM ONDERZOEK. DEPT. LANDBOUW. 1901-1928. Jaarboeken 1901:119; 1905:112, 127, 128, 129; 1906:76, 77, 320, 323, 346; 1907:184, 187, 197; 1908:80, 81, 85, 86, 87; 1909:174, 177; 1911:128, 131, 370; 1913:39, 43, 51, 55; 1914:96, 104; 1915:53, 67, 68; 1916:42, 43; 1917:41, 49; 1924:24; 1928:68.
- * NEDERLANDSCH - INDIE. ALGEMEEN LANDBOUW SYNDIKAAT E. AANVERW. ORGANISATIES 1940. Jaarverslag 1940, p. 231.
- * NED.-IND. LANDBOUW SYNDICAAT HANDEL. 1909. 10de Congres, 27-28 Aug., 1909 te Bandoeng. 2a Ged. Verslag groene bemesting. nos. 9, 12, 28, 64.
- * NETSCHER, H. J. TH. 1893. Liberia - koffie. *Teysmannia* 4, pp. 309-402.
- Notulen, 1934. See Malangsche Landbouw Vereeniging. 1934.
- Notulen, 1940. See Besoekische Landbouw. 1940.
- NUTMAN, F. J. 1933. The root system of *Coffea arabica*. I. Root systems in typical soils of British East Africa. *Empire Journal of Experimental Agriculture* 1(3):271-284.
- _____ 1933a. The root system of *Coffea arabica*. II. The effect of some soil conditions in modifying the "normal" root system. *Empire Journal of Experimental Agriculture* 1(4):285-296.
- * OS, H. G. van. 1920. Mechanisch ontslijmen, wasschen en voordrogen in de koffie bereiding. Bandoeng. *Algemeen Landbouw Weekblad voor Ned.-Ind.* 5(14):317.
- OSS, I. F. van. 1927. Warenkennis en technologie. *Koffie (Amsterdam)* 2:1056, 1059.
- OSTENDORF, F. M. 1938. Onze cultuurplanten en hun milieu. *Bergcultures* 12(27):878-883.
- * OTTOLANDER, T. 1898. Over het snoeien van koffiebomen. *Teysmannia* 9:422.
- + _____ 1900-1901. Hybridisatie. *Koffiegids* 2:651, 762, 766.
- + _____ 1903-1904. Eenige opmerkingen over schaduwboomen voor koffie. *Cultuurgids* 5:673.
- + _____ 1905. Gegevens betreffende het schadurvraagstuk; Verslag 8ste, Congres Alg. Syndicaatie e.a. *Bergcultures in N. I., Soerabaja, December 1905.* *Cultuurgids* 1:82.
- _____ 1936. Het enten van koffie. *Bergcultures* 10(11):360-367; (12):394-401; (14):468-472; (15):498-504; (16):535-537; (17):555-560. (Reprinted from the series of articles published in *De Koffie - Gids* in 1899.
- Overzicht... 1929. See Anonymous 1930a.
- P. T. 1937. See Anonymous 1937.
- PAERELS, B. H. 1927. Agronomische beschrijving van de koffiecultuur in de Zuidelijke Toradjaland (Celebes). *Buitensorg. Afdeling Landbouw. Mededeeling no. 11.* p. 86.
- PASQUIER, R. du. 1928. La culture du caféier dans le sud des Indes. *Bulletin Economische Indochine* 31(191):49.

- * PEERBOOM VOLLER, D. 1904-1905. Iets over de cultuur van takenten van koffie - hybriden in Oost - Java. *Cultuurgids* 6:967, 987.
- * PENZIG, O. 1921. *Pflanzen teratologia*. I. Berlin. 448 p.
- PFALTZER, A. 1934. Beschouwingen over besafval bij Robusta. *Bergcultures* 8(46):1094.
- + _____ 1935. De stand van onze kennis omtrent wortelschimmels bij hevea. *Bergcultures* 9(37):850.
- + _____ 1935a. Een onderzoek over de aantasting der koffiewortels door aaltjes. *Archief voor de Koffiecultuur* 9(2):55.
- + _____ 1936. Ziekten en plagen. *Bergcultures* 10(32):988.
- _____ 1937. De bestrijding van topsterfte. *Bergcultures* 11(30):1395-1400.
- + _____ 1937a. Mededeeling over proeven ter bestrijding van de schade door koffie - aaltjes aangericht. *Bergcultures* 11(38):1363, 1367-1368.
- + _____ 1940. Topsterfte bestrijding special in verband met rejuvenatie. *Bergcultures* 14(7):228.
- _____ & FLUITER, H. J. de. 1941. De wortelluisschimmel, Polyporus coffea Wakef. *Archief voor de Koffiecultuur* 15:121-142.
- * PIERAERTS, M. J. 1918. Expertises chimiques d'échantillons de produits agricoles congolais. *Bulletin Agricole du Congo Belge* 9(14):164-165.
- PIERROT, E. 1906. *Culture pratique et rationnelle du caféier et préparation du grain pour la vente*. Paris, A. Challamel. 92 p.
- PORTERES, R. 1934. Etude sur le phénomène de virescence des caféiers a la station de Bingerville. *Comité d'Etudes Historiques et Scientifiques de l'Avrique Occidentale Française*. Paris. *Bulletin* 17(3):417-427.
- _____ 1936. Note botanique sur le Coffea excelsa, A. Chev. (sensulato) et le Coffea macrochlamys K. Schum. *Revue de Botanique Appliquée et d'Agriculture Tropicale* 16:45-49.
- _____ 1938. Le café Indénié de la Cote d'Ivoire. *Agronomie Coloniale* 27(252):161-168.
- _____ 1939. Le choix des variétés et l'amélioration des caféiers en Cote d'Ivoire. *Revue de Botanique Appliquée et d'Agriculture Tropicale* 19(209):18-29.
- POUPART, Y. 1938. Notes sur la culture du "Coffea arabica" en Cote d'Ivoire. *Agronomie Coloniale* 27(252):170-171.
- * PREHN, R. A. van. 1936. Prophylactische luisbestrijding. *Bergcultures* 10(29):907.
- * PREYER, R. A. 1901. Butin Schaap's koffie enting. *Indische Mercur* 24(26):494.
- PRILLWITZ, P. M. H. H. 1931. Albizzia sumatrana als schaduwboom in theetuinen. *Archief voor de Theecultuur* 3:129-134.
- _____ 1935. Het oculeeren van steriele lamtoro (Leucaena glauca Benth.) *Bergcultures* 9(20):441-446.
- * PRINS, A. 1878. Handleiding voor de koffiecultuur op Java volgens de werkwijze op Ceylon. *Semerang*.

- * PRINS, A. 1895. Open vraag betreffende productieve waarschijnlijkheden bij de Liberia cultuur op Java. Indische Mercur 18(43):617.
- * PROSMAN, C. 1937. Lessen uit den crisistijd. Bergcultures 11(25):911.
- PUERTO RICO. (MAYAGUEZ) AGRICULTURAL EXPERIMENT STATION. 1935, 1939. Report, 1935, p. 22; 1939, p. 27.
- * PUNTER, J. 1901-1902. Slaagt het enten van Java - en Maragogype - koffie op Liberica? Cultuurgids 3:119, 137.
- + _____ 1908. De snoei der Liberia - koffie. Cultuurgids 8:414-416.
- * QUANJER, H. M., THUNG, T. H. & ELZE, D. L. 1928-1929. De virusziekten der planten. Landbouw 4:625, 631.
- Questions - Liberian coffee 1876. See Anonymous 1876.
- RAAFF, TH. E. 1930. Bemestingsproeven bij koffie. Bergcultures 4(32):840-843.
- _____ 1931. De beteekenis der groenbemesters voor de koffiecultuur. Verslag 10^e vergard. Vereen. Proefstation Person. pp. 40-46.
- * RANT, A. 1911. De djamoer oepasziekte in het algemeen en bij kina in het bijzonder. Meded. Landbouw no. 13. p. 18, 34.
- RENARDEL DE LAVALETTE, G. CH. & SCHOL, L. 1902. Cited in De Noodlijdende koffiecultuur. Indische Mercur 25(30):363.
- REYDON, G. A. 1926. Enkele opmerkingen over krommingen van koffie-penwortels. Bergcultures 1(13):350-351.
- _____ 1933. Een bladziekte bij koffie. Bergcultures 7(27):758-762.
- _____ 1933a. Het vraagstuk der bestrijding van koffie - aaltjes. Bergcultures 7(1):2-10.
- _____ 1933b. Nota inzake witte luis op de onderneming Soember Wadoeng gedurende de regennaanden. Bergcultures 7(35):977-983.
- + _____ 1935. Infectieproeven met reïnculturen van koffie - aaltjes. Archief voor de Koffie-cultuur 9:27, 39.
- RIGAUD, A. 1896. Traite pratiqué de la culture du café dans la région centrale de Madagascar. Paris. 102 p.
- RINGOET, A. 1935. Notes sur la préparation du café. Institut National pour l'Etude Agronomique du Congo Belge (INEAC) Série Technique no. 1 pp. 5-52.
- RIPPERTON, J. C., GOTO, Y. B. & PAHAU, R. K. 1935. Coffee cultural practices in the Kona District of Hawaii. Hawaii Agricultural Experiment Station Bulletin no. 75. 64 p.
- ROCHETTE, H. 1935. Culture et sélection du caféier en Cote d'Ivoire. Revue de Botanique Appliquée et d'Agriculture Tropicale 15(161):32-39.
- ROELOFSEN, P. A. 1939. Beïnvloeding en behoud van de Kwaliteit van Robusta - marktkoffie. Bergcultures 13(24):812-817.

- + ROELOFSEN, P. A. 1939a. Het langdurig opslaan van koffie en cacao. *Bergcultures* 13(37):1303.
- _____ 1939b. Microscopisch onderzoek van gebrande gemalen koffie op surrogaten. *Archief voor de Koffiecultuur* 13(3):282-293.
- _____ 1939c. Onderzoekingen over beïnvloeding en behoud van de Kwaliteit van Robusta - marktkoffie. *Archief voor de Koffiecultuur* 13(3):151-281.
- _____ 1939d. Het stekken van koffie. *Bergcultures* 13(29):994-1002.
- _____ 1940. Aanvullende proeven over het stekken van koffie. *Archief voor de Koffiecultuur* 14(2):105-118.
- _____ & COOLHAAS, C. 1939. Over het stekken van koffie, stimuleering van de wortelvorwing en groeistofbehandeling bij het enten. *Archief voor de Koffiecultuur* 13(2):87-150.
- ROEPKE, W. 1919. Gegevens omtrent de koffie bessenboeboek (Stephanoderes hampei Ferr. coffea). Buitenzorg, Instituut voor Plantenziekten. Mededeeling no. 38. 33 p.
- + ROMBURGH, P. van. 1892. Aanteekeringen over de in den cultuurtuin te Tjikeumeuh gekweekte gewassen.
- + _____ 1896. Koffie - schillen als mest in koffietuinen. *Teysmannia* 7. p. 379.
- + _____ 1899. Een te weinig gebruikte schaduwboom, (Caesalpinia dasyrachis Miq.). *Teysmannia* 10. pp. 483, 582.
- _____ 1901. Coffea stenophylla. *Teysmannia* 12(12):605-610. (See also Staatsblad no. 315. 1936).
- _____ 1903. Eenige aantekeningen over de in Buitenzorg gekweekte Coffea stenophylla Don. *Teysmannia* 13. pp. 368, 369.
- _____ & WIGMAN, H. J. 1896. Over de Liberia - koffiecultuur op Java. *Teysmannia* 7. pp. 509, 516, 552, 557, 621.
- ROMERO, T. 1930. Multiplication of selected coffee trees in the College of Agriculture by grafting. *Philippine Agriculturist* 19(1):53-67.
- ROOS, J. 1937. Over de kwaliteit van bevolkingskoffie voornamelijk bevolkingsrobusta's. *Landbouw* 13(7-8):503-513.
- RUDIN, W. F. 1930. Periodieke verjonging van gemengde dadap - en lamtoro schaduw in combinatie met grond - bewerking. *Bergcultures* 4(9):219-223, 244-250.
- _____ 1935. Beschouwingen over cultuurtechnische en economische vraagstukken bij de ondernemings robusta - cultuur in de humide streken van Zuid - Sumatra I, IV. *Bergcultures* 9(33):733-743; (48):1299-1302.
- + _____ 1935a. Over alang - alang - bestrijding. *Bergcultures* 9(15):346.
- _____ 1936. De bevolkingskoffiecultuur in de Marga Ranau. (Residentie Palembang) *Landbouw* 11(7-8):266-325.
- + _____ 1936a. Over het tempo bij het geleidelijk verjongen (door diepsnoei) van doorgeschoten of dichtgegroeide Robusta - koffie plantsoenen. *Bergcultures* 10(14):462, 465.
- _____ 1937. Topsterfte bestrijding in de practijk. *Bergcultures* 11(9):289-291; (23):847-849; (41):1471.

- RUDIN, W. F. 1938. Het economisch aspect van arbeidsintensieve cultuurmaatregelen bij wisselende conjunctuur. *Bergcultures* 12(29):994, 999.
- SABONADIÈRE, W. 1870. The coffee planter of Ceylon. London. 216 p.
- + SAMPSON, H. C. 1930. Agriculture in Sierra Leone. *Kew Bulletin* pp. 225, 233.
- SCHELTEMA, A. M. P. A. 1932. De koffiecultuur in de residenties Bondowoso en Djember. *Bergcultures* 6(8):206-209.
- + _____ 1935. Koffieconsumptie in Ned.-Indie. *Bergcultures* 9(50):1371, 1372.
- SCHWEIZER, J. 1925. De koffieproeftuin op Kendeng Lemboe. *Bergcultures* 3(56):1426-1430.
- _____ 1925a. Over het verschil in vatbaarheid voor boesboekaantasting bij koffie. *Koffiebessenboeboek Fonds. Mededeeling no. 11.* pp. 287-314.
- _____ 1927. Kiemfysiologische proeven met koffiezaad. *Archief voor de Koffiecultuur* 1(6):249-271.
- _____ 1930. The selection of *Coffea arabica*. Pacific Science Congress, IV. (Java) *Proceedings* 4:265-270.
- _____ 1931. Over problemen, de gemengde cultures betreffende. *Bergcultures* 5(5):119-124. (Discussion pp. 124-125).
- _____ 1931a. Overblijfselen van een oude cultuur op Java (Java - koffie). *Bergcultures* 5 (extra no.):55-59.
- _____ 1931b. Verslag over het jaar 1930. *Besoekische Proefstation. Mededeeling no. 43.* p. 47.
- _____ 1932. Over het enten als middel ter verbetering van een bestaanden koffie - aanplant. *Bergcultures* 6(18):451-458.
- _____ 1932a. Verslag over het jaar 1931. *Besoekische Proefstation. Mededeeling no. 48.* pp. 56, 57.
- _____ 1933. Bijdrage tot de physiologie van den koffiesnoei. *Bergcultures* 7(32):926-937.
- + _____ 1933a. Verslag over het jaar 1932. *Besoekische Proefstation. Mededeeling no. 49.* pp. 33, 68, 69, 74.
- _____ 1934. Physiologische bijdrage tot het stumpen en coupeeren van koffiebibit. *Bergcultures* 8(8):168-182.
- _____ 1935. Beschouwingen over gemengde cultures. *Bergcultures* 9(14):1039-1048.
- _____ 1935a. Hydratur - und assimilations - Bestimmungen bei Feldversuchen in den Tropen. *Handelingen van het 7^e Ned.-Ind. Natuurwetensch. Congress, 1935.* pp. 436-446.
- + _____ 1935b. Over physiologische verschijnselen bij enkele cultuurplanten gedurende abnormale droogte. *Verslag 15, Vergard, Vereen. Proefstation Person.* pp. 72, 168, 170.
- + _____ 1936. Hydratuuurbepalingen bij koffie in verband met de voeding. *Verslag 16, Vergard. Vereen. Proefstation Person.* pp. 207, 214.
- _____ 1936a. Over de variabiliteit en erfelijkheid van de grootte der koffieboon. *Bergcultures* 10(21):654-661.

- SCHWEIZER, J. 1939. Demonstratie van koffie - takenten op Kaliwining. *Bergcultures* 13(28):954-965.
- + _____ 1939a. Over de functie van het blad bij het cultuurgewas gedurende een vegetatieperiode. *Bergcultures* 13(47):1628-1632.
- _____ 1939b. Over het pagger - plantverbandstelsel bij rubber en koffie. *Bergcultures* 13(3):74-87.
- _____ 1940. Over lamtoro - soorten als houtleveranciers in een koffietaanplant. *Bergcultures* 14(34):1069-1077.
- _____ 1940a. Physiologische studies bij koffie. I. De chemische samenstelling van het blad in verband met seizoen en vruchtbaarheid. *Archief voor de Koffiecultuur* 14(2):165-198.
- + _____ 1940b. Verdere gegevens over het paggersysteem bij Hevea. *Bergcultures* 14(52):1668-1669.
- _____ 1941. Wat haalt een koffie en rubber - aanplant uit den grond en wat geven zij aan den grond terug. *Bergcultures* 15(22):704-711.
- _____ & JACOB, J. G. s. 1938. Eerste resultaten van a tweetal onderstam - proeven bij Robusta - enten op Kaliwining en Djember. *Bergcultures* 12(45):1526-1532.
- SENSTUIS, M. W. 1916. Beschrijving der koffiegronden van Pasoeroean en Kediri. Malang. Proefstation Mededeeling no. 15. 15 p.
- Services Phytopathologique et Agricole. 1933. See Kivu. Mulungu Station. 1933.
- + SETTEN, D. J. G. van. 1917. Iets over de bereiding van kleinere hoeveelheden robusta - koffie. *Teysmannia* 28. p. 171.
- SIBERT, EDMOND. 1932. Les caféiers de la Cote d'Ivoire. Première partie: Botanique et culture. Paris, Centre d'Etudes Coloniales. 94 p. (Reviewed by A. Chevalier in *Revue de Botanique Appliquée et d'Agriculture Tropicale* 13(137):75-78. 1933).
- _____ 1938. Technologie du café; les caféiers de la Cote d'Ivoire. II. Rouen. 112 p.
- s' Jacob, J. C. See Jacob, J. C. s.
- SIMMONDS, P. L. 1864. Coffee and chicory; their culture, chemical composition, preparation, etc. London. 102 p.
- SLADDER, G. E. 1931. Le café en Colombie. *Annales Gembloux* 37:295-324.
- _____ 1931a. L'emploi des engrais verts et des plantes de couverture dans la culture du caféier. *Bulletin Agricole du Congo Belge* 22(3):367-385.
- _____ 1933. Le jardin semencier de Bangelan (Java). *Bulletin Agricole du Congo Belge* 24(1):3-44.
- + SLANEY, A. J. 1893. Koffie - bladthee. *Indische Mercur* 16(41):613.
- SNOEP, W. 1932. Beschouwing over het "laanverband" als vorm van permanent gemengde cultuur. *Bergcultures* 6(34):889-898.
- _____ 1932a. Bestrijding der gramangieren in den Westmoesson. *Bergcultures* 6(22):545-548.
- _____ 1932b. Over cultuurmaatregelen betreffende bodembehandeling en schaduw bij koffie. *Bergcultures* 6(52):1413-1417; (53):1450-1453.

- SNOEP, W. 1932c. Over organische bemesting in verband met het gebruik van koffieschil als zoodanig. Bergcultures 6(4):87-92.
- _____ 1932d. Verschijnselen in een koffie - aanplant op veengrond. Bergcultures 6(27):687-691.
- _____ 1933. Behandeling van koffieschillen voor organische bemesting. Bergcultures 7(13):360-364.
- _____ 1935. Koffieproducties en regenval. Bergcultures 9(40):982-992.
- _____ 1936. Bemestingsproeven bij jonge koffie in het Oost - Java ressort van het Proefstation Midden - en Oost - Java. Bergcultures 10(30):918-922.
- _____ 1936a. Grondanalyses in het Oost - Java ressort van het Proefstation Midden - en Oost-Java. Archief voor de Koffiecultuur 10(3):255-277.
- _____ 1936b. Koffieproductie - gegevens van Soember Asin. Archief voor de Koffiecultuur 10(3):219-229.
- _____ 1936c. Koffieproducties. Bergcultures 10(33):1002-1004.
- _____ 1936d. Over de bepaling van de bloeigrootte en de bloei en vruchtslagings bij koffie. Bergcultures 10(20):618-626.
- _____ 1936e. Problemen bij de koffiecultuur op den Kloet. Bergcultures 10(8):231-237; (9):287-290.
- _____ 1937. Over de variabiliteit van boomproducties bij koffie. Bergcultures 11(5):137-144.
- _____ 1937a. Tegenwoordige vormen van bodembehandeling bij koffie. Bergcultures 11(32):1158-1164.
- _____ 1939. Productiecijfers van robusta - cloonen in het ressort van het Proefstation Midden - en Oost - Java. Bergcultures 13(20):652-661.
- _____ 1939a. Rejuvenatie en herontginning bij koffie. Bergcultures 13(24):804-810.
- _____ 1940. Bepaling omtrent de stof meelverspreiding voor de lucht bij Robusta - koffie. Archief voor de Koffiecultuur 14:275-281.
- _____ 1940a. Bijzonder resultaat van twee bodembehandelingsproeven bij jonge koffie. Bergcultures 14(41):1296-1302.
- _____ 1940b. Enkele gegevens over de bloeigrootte en het bloeirendement, als productie-factoren, bij Robusta - koffie. Archief voor de Koffiecultuur 14:247-273.
- _____ 1941. Boniteitsfactoren bij koffiegronden en de invloed daarop van bodembehandeling. Archief voor de Koffiecultuur 15:143-185. (Also in Bergcultures 15(20):640, 645. 1941).
- + _____ 1941a. Productiegegevens van koffie - cloonen in het ressort van het Proefstation Midden - en Oost - Java. Bergcultures 15(13):399-408.
- _____ 1941b. Resultaten van bemestingsproeven bij Koffie in het van Malangsch ressort van het Proefstation Midden - en Oost - Java. Bergcultures 15(30):1000-1010.
- SNOEP, W. & VEEN, R. van der. 1941. Enkele gegevens in een beschouwing over plantverband bij koffie. Bergcultures 15(7):180-185.
- SOEKABOEMISCHE EN BATAVIAASCHE LANDBOUWVEREENIGING. 1891-1896. Jaarverslag, 1891, 1892, 1895, 1896.

- + SOEKABOEMISCHE EN BATAVIAASCHE LANDBOUWVEREENIGING. 1897. Liberia - koffie - pulper; notulen der buitengewone algemeene gecombineerde vergadering op 19 Januari, 1897. Indische Mercur 20(13):156.
- + _____ 1898. Indische Mercur 12(17):252.
- + _____ 1900-1901. De koffie op de algemeene vergadering van 15 April 1900. Koffiegids 2:340.
- + SOMEREN BRAND, J. E. van. 1916. De groote cultures der wereld. 2d ed. Amsterdam.
- + SPALL, P. W. A. van. 1861. Verslag over de koffie - en kaneelcultuur op het eiland Ceylon in het jaar 1861. Batavia. p. 99.
- SPRECHER VON BERNEGG, A. 1934. Tropische und subtropische Weltwirtschaftspflanzen ihre geschichte, kultur und volkswirt - schaftliche Bedeutung. Stuttgart, Ferdinand Enke, pp. 1-264.
- STADT, D. 1930. De malaise in de koffiecultuur en hare problemen. Bergcultures 4(32):843-847.
- _____ 1930a. De selectie op een koffie - onderneming. Bergcultures 4(19):495-498.
- _____ 1931. Is de takkenboeboek als een tijdelijke ramp te beschouwen of wordt ze de ondergang van de Robusta - cultuur? Bergcultures 5(39):1073-1077.
- STAHEL, G. 1917. De zeefvatenziekte (Phoëmcrose) van de Liberia koffie in Suriname ("koffie - wortelziekte"). Suriname. Department van den Landbouw Bulletin no. 12. 2 p.
- _____ 1934. De tegenwoordige stand van het onderzoek naar den overdragen der zeefvatenziekte van de koffie. Suriname. Landbouw Proefstation Mededeeling no. 7. 9 p.
- STEENIS, C. G. G. J. van. 1938. Hoe heeten de opgerichte en liggende vormen van "Salvia occidentalis WS"? Bergcultures 12(48):1636-1640.
- + STEIN CALLENFELS, P. V. van. 1916. Een praatje over de koffiecultuur onder de compagnie. Ned.-Ind. Landbouw Syndicaat Publicatie 8. pp. 28, 36, 40, 52.
- STEINMANN, A. 1925. Wortelsiekten van de koffie. Archief voor de Koffiecultuur 1(1):79-85.
- + STENNEKES, L. 1898. De "Hooglands koffie van Sierra Leone" voor Java. Indische Mercur 21(40):619, 620. Also in English "Highland coffee of Sierra Leone (Coffea stenophylla, C. Don)" Kew Bulletin of Miscellaneous Information 1896:189-191.
- + STIBBE, M. J. 1915. Geselecteerd Pasoemah - zaad van Coffea arabica op Pantjoer. Teysmannia 26:218.
- + _____ 1923. Termijhandel op Java. Economische Statische, Bericht 8(413):1014.
- STOFFELS, E. 1936. La sélection du caféier arabica a la Station de Mulungu. Institut National pour l'Etude Agronomique du Congo Belge (INEAC), Serie Scientifique no. 11. 41 p.
- _____ 1937. La taille du caféier arabica au Kivu. Institut National pour l'Etude Agronomique du Congo Belge (INEAC) Serie Technique no. 12. 35 p.
- + STOPPELAAR, A. de. 1903-1904. De Coffea robusta op den Smeroe. Cultuurgids 5:321.
- + STOPPELAAR, J. J. de. 1934. Beknept uittreksel van de inleiding over het verjongen van koffie. Bergcultures 8(34):811.
- _____ 1934a. Over het verjongen van koffie. Bergcultures 8(41):966-974.

- * STOPPELAAR, J. J. de. 1936. Is er sprake van degeneratie van robusta? *Bergcultures* 10(38): 1160, 1163.
- + _____ 1936a. Wat is een goede koffieboom en hoe verkrijgt men dien? *Bergcultures* 10:313, 315, 317.
- + _____ 1937. Takenten maken op overjarige onderstammen op de beden. *Bergcultures* 11(13):347.
- _____ 1939. Snoei - en takent - problemen in de koffiecultuur. *Bergcultures* 13(38):1326-1332.
- * STUHLMANN, F. 1902. Studienreise nach Niederlandisch und Britisch - Indien. *Tropenpflanzer* 6:181.
- * STURLER, W. L. de. (n.d.). Algemeene opmerkingen betreffende de teelt en de behandeling der Koffie. Haarlem.
- * SUERMONTD LZN, W. 1901. Yields of arabica. *Indische Mercur* 24(17):291.
- * SURINAME. DEPARTMENT LANDBOUW ECONOMISCHE ZAKEN. 1936-1939. Verslag, 1936, 1937, 1938, 1939.
- * SURINAME. DEPARTMENT LANDBOUW - PROEFSTATION. 1924-1933. Verslag, 1924-1927, p. 9; 1928-1930, p. 30; 1931-1932, p. 24; 1933.
- SWYNNERTON, C. M. P. & PHILIPSON, W. R. 1936. A new Coffea from Portuguese East Africa. *Journal of Botany (London)* 74:314-322.
- TASCHDJIAN, E. 1928. Observations concernant la variabilité, la dominance et le vicinisme chez le Coffea arabica. *Bulletin Economische Indochine* 35. p. 531.
- TERGAST, G. C. W. CHR. 1930. Monographie over de bevolking - koffiecultuur in Nederlandsch - Indië. Afdeling Landbouw Mededeeling no. 15. 48 p.
- THISELTON DYER, W. T. 1880. The coffee - leaf disease of Ceylon. *Quarterly Journal of Microscopical Science (n.s.)* 20:119-129.
- THOMAS, A. S. 1940. Shade trees in Uganda and their relation to the cultivation of coffee and tea. *East African Agricultural Journal* 5(4):287-293. (Dutch translation appears in *Bergcultures* 14(5):493-?).
- THURBER, F. B. 1881. Coffee: from plantation to cup. New York, American Grocer Publishing Association. 416 p.
- TISSERANT, R. P. CH. 1929. Les caféiers sauvages de l'Oubangui Français. *Revue de Botanique Appliquée et d'Agriculture Tropicale* 9(89):27-30.
- TISSOT, P. 1938. L'Ethiopie et sa mise en valeur agricole. *Revue de Botanique Appliquée et d'Agriculture Tropicale* 18(202):401-413.
- _____ 1939. Production et commerce du café en Ethiopie. *Revue de Botanique Appliquée et d'Agriculture Tropicale* 19(211):173-177.
- * TONN, O. L. W. 1932. Iets over het coffeine - vrij maken van koffie aan de hand van de Duitsche patentliteratuur. *Pharmaceutisch Tijdschrift* 9:123.
- * TOXOPEUS, H. J. 1937. De verruiming van de mogelijkheid voor de planten - veredeling als gevolg van de vorderingen van grond - leggend onderzoek. Verslag 17, Vergard. Proefstation Person. p. 70, 71.

- TRAUTMANN, F. F. K. 1932. Gramang - bestrijding. *Bergcultures* 6(15):379-381, 383, 385.
- + TREUB, M. 1892. Gedenkboek's Lands plantentuin 18 Mei 1817-18.
- + _____ 1906. Een proeftuin voor selectie bij Liberia - koffie. *Teysmannia* 17:648.
- + _____ 1910. Landbouw. Januari 1905 - October 1909.
- + UGARTE, J. P. 1920. Preparing coffee for the market. *Tropical Agriculturist (Ceylon)* 54:265.
- UKERS, W. H., ED. 1934. Ukers' tea and coffee buyers' guide. Annual. New York. pp. 26, 50.
- _____ 1935. All about coffee. 2d ed. New York, Tea & Coffee Trade Journal Co. 818 p.
- + ULTEE, A. J. 1908. Over het vruchtvleesch van Java - Liberia - en Robusta - koffie. *Cultuur-gids* 10(4):63-67.
- + _____ 1915. Jaarverslag van Directeur, 1914. *Besoekische Proefstation Mededeeling* no. 17. 4 p.
- + _____ 1917. Koffie in Hevea - tuinen. *Teysmannia* 28:199-200.
- _____ 1922. De proeftuin voor de Bergcultures van het Besoekische Proefstation. *Besoekische Proefstation Mededeeling* no. 33. pp. 3-33.
- + _____ 1924. Het onderhoud van den Robusta - aanplant. *Bandoeng. Algemeen Landbouw Weekblad voor Ned.-Ind.* 8(50):1539, 1540.
- _____ 1924a. Resultaten der enquete over groenbemesters en aanvullende mededeelingen. *Malang Proefstation Mededeeling* no. 45. pp. 9-15.
- _____ 1926. De droogte en de cultures, in het bijzonder de koffiecultuur. *Archief voor de Koffiecultuur* 1(4):167-171.
- _____ 1926a. De toekomst der koffiecultuur in Nederlandsch - Oost - Indië. *Bergcultures* 1(23):628-632.
- _____ 1927. Curiosum. (Book review of Cheney's "Coffee; a monograph of the economic species of the genus *Coffea* L."). *Bergcultures* 2(2):36.
- _____ 1927a. Een en ander uit de geschiedenis der koffiecultuur van de laatste 30 jaar. *Bergcultures* 1 (36):1033-1037.
- _____ 1928. Bemesting van koffie. *Verslag 8, Vergard. Vereen. Proefstation Person.* pp. 82-130.
- _____ 1928a. Over het optreden der topsterfte van de koffie op Java. *Bergcultures* 2(43):1290-1291.
- _____ 1928b. Verslag over de werkzaamheden van het Proefstation Malang in het jaar 1927. *Malang Proefstation Mededeeling* no. 65. (Verslag Dr. Hille Ris Lambers, pp. 22-29).
- _____ 1929. De optimale omstandigheden voor de koffiecultuur. *Bergcultures* 3(68):1737-1740.
- _____ 1931. Oude koffietuinen. *Bergcultures* 5(2):45-59.
- _____ 1931a. Het proefstationwezen gedurende de laatste 25 jaren. *Bergcultures (Extra no.)* pp. 37-38.

- ULTEE, A. J. 1931b. De redding van de koffiecultuur. (Curiosum). Bergcultures 5(8):218, 219.
- _____ 1931c. De takkenboek. Bergcultures 5(40):1098-1100.
- + _____ 1932. Aanteekeningen; is er achteruitgang van onse Robusta - aanplantingen te constateren? Bergcultures 6(10):253-254.
- _____ 1932a. Enkele beschouwingen over de Robusta cultuur. Bergcultures 6(30):774-777.
- _____ 1932b. Ons koffie - plantmateriaal. Bergcultures 6(12):304-308.
- _____ 1933. Beschouwingen over de koffiecultuur. Bergcultures 7(13):368-372.
- _____ 1933a. Het bewaren van zaadkoffie. Archief voor de Koffiecultuur 7(2):75-83.
- _____ 1934. Beschouwingen over de koffiecultuur. II. Snoei bij Robusta. Bergcultures 8(37):865-869.
- _____ 1934a. De invoer van Robusta in Nederlandsch - Indië. Bergcultures 8(9):190-191.
- _____ 1934b. Koffie in en buiten Ned.-Ind. Landbouwkundig. Tijdschrift 46(560):345-354.
- + _____ 1934c. Het vraagstuk der koffie - fermentatie. Bergcultures 8(13):285.
- + _____ 1935. Nogmaals de koffiefermentatie. Bergcultures 9(28):631.
- + _____ 1935a. Publicaties over koffiegonden en bemesting. Bergcultures 9(42):1094.
- + _____ 1936. Desinfectie van zaadkoffie. Bergcultures 10(2):59.
- UTERMARK, W. L. 1925. Over koffiesetten. Indische Mercur 48(12):179.
- + VALETTE, J. C. 1905. De zaadboomen van Pondok Gedeh. Cultuurgids 7:935.
- van Brugge, W. C. See Brugge, W. C. van.
- van Delden, A. J. W. See Delden, A. J. W. van.
- van Delden, Learne C. F. See Delden, Learne C. F. van.
- van den Abeele, M. See Abeele, M. van den.
- van den Berg, M. P. See Berg, M. P. van den.
- van der Goot, P. See Goot, P. van der.
- van der Meulen, A. See Meulen, A. van der.
- van der Veen, R. See Veen, R. van der.
- van der Weele, H. W. See Weele, H. W. van der.
- van der Wolk, See Wolk, van der.
- van Doorn, J. F. See Doorn, J. F. van.
- van Gorkum, K. W. See Gorkum, K. W. van.
- van Gorkum, V. G. See Gorkum, V. G. van.

- van Hall, C. J. J. See Hall, C. J. J. van.
- van Helten, W. M. See Helten, W. M. van.
- van Heusden, W. C. See Heusden, W. C. van.
- van Hooff, N. W. S. See Hooff, N. W. S. van.
- van Kleef, H. See Kleef, H. van.
- van Laer, A. See Laer, A. van.
- van Lennep, H. H. T. See Lennep, H. H. T. van.
- van Maanen, G. W. F. See Maanen, G. W. F. van.
- van Os, H. G. See Os, H. G. van.
- van Oss, I. F. See Oss, I. F. van.
- van Prehn, R. A. See Prehn, R. A. van.
- van Romburgh, P. See Romburgh, P. van.
- van Setten, D. J. G. See Setten, D. J. G. van.
- van Slooten, D. F. See Slooten, D. F. van.
- van Someren Brand, J. E. See Someren Brand, J. E. van.
- van Spall, P. W. A. See Spall, P. W. A. van.
- van Steenis, C. G. G. J. See Steenis, C. G. G. J. van.
- van Stein Callenfels, P. V. See Stein Callenfels, P. V. van.
- van Wel, A. R. See Wel, A. R. van.
- VAVILOV, N. I. 1922. The law of homologous series in variation. *Journal of Genetics* 12:47-90.
- _____ 1926. Studies on the origin of cultivated plants. Leningrad, 248 p.
- * VEEN, R. van der. 1934. Bodentypen in het ressort van het Besoekische Proefstation, Mededeeling no. 51.
- _____ 1934a. Kunstmatige rijping van koffiebessen door middel van aethyleen. *Bergcultures* 8(46):1087-1092.
- _____ 1934b. Resultaten van twee schaduwproeven. *Bergcultures* 8(45):1063-1067.
- + _____ 1934c. Verbetering van den grond. *Bergcultures* 8(45):1071-1072.
- + _____ 1935. Bessenboek - aantasting in Besoeki in 1934. *Bergcultures* 9(20):457.
- _____ 1935a. Over den invloed van het bodemdek op koffie en rubber. *Bergcultures* 9(40):961-969.
- + _____ 1938. Iets over den invloed van bemesting op de roodbruine Yangbergkleigronden. *Bergcultures* 12(8):217.

- VEEN, R. van der. 1938a. Krome penwortels. *Bergcultures* 12(9):256-260.
- _____ 1938b. Veengrond op een koffieland. *Bergcultures* 12(12):345-347.
- _____ 1939. De koffiecultuur in Centraal - en Oost - Afrika. *Bergcultures* 13(24):819-823.
- _____ 1940. Stikstofbemesting door leguminosen. *Archief voor de Koffiecultuur* 14(2):119-131.
- _____ 1940a. Voedingsfysiologische onderzoekingen bij koffie. III. *Archief voor de Koffiecultuur* 14(3):199-224.
- _____ 1941. Koffieproducties. *Bergcultures* 15(10):278-285.
- + VEENDORP, H. & BAAS BECKING, L. M. G. 1587-1937. 1938. *Hortus Academicus Lugduno. Batavus. Verslag 1873-1904. See Buitenzorg 1873-1904.*
- Verslag. 's Lands Plantentuin. 1909. *See Bangelan. 's Lands Plantentuin. 1909.*
- Verslag 1924-1933. *See Suriname. Department Landbouwproefstation. 1924-1933.*
- Verslag 1936-1933. *See Suriname. Department Landbouw - economische Zaken. 1936-1939.*
- + VERSLUIJS. 1903-1904. Over den groei der Coffea robusta op het Jang - gebergte. *Cultuurgids* 5:30.
- VINK, G. J. 1929. Over de koffiecultuur der Baliërs. *Landbouw* 5(1):1-78.
- + VISSCHER, C. J. 1936. Madagascar - koffie. *Ned.-Ind. Economische Weekblad* 5(41):1927-1928.
- + VOGEL, C. J. de. 1895. De koffiecultuur op de onderneming Kandangan (res. Madioen) Koloniale Museum te Haarlem. no. 10. p. 11.
- + VOGLER, K. W. M. 1899-1900. Veredeling door vermenig - vuldiging, hybridisatie, enten in betrekking tot de Java - koffie - cultuur. *Koffiegids* 1:307-310.
- + _____ 1900-1901. Is er al dan niet degeneratie? *Koffiegids* 2:693, 729.
- von Faber, F. C. *See Faber, F. C. von.*
- VOUTE, C. & HALL, C. J. J. van. 1914. Tweede verslag van robusta - selectie op Banaran. Midden - Java. Proefstation Mededeeling no. 15. p. 11.
- VRIES, H. de. 1901. Die Mutations theorie: Versuche und Beobachtungen über die Entstehung von Arten im Pflanzenreich. Leipzig, Veit & Co. p. 126.
- + WALLER, L. 1887. Liberia - koffie. *Indische Mercur* 10(19):249.
- + WALLER, TH. 1919. Het toppen van Liberia koffie. *Suriname Dept. Landbouw Bulletin* no. 31. 23 p.
- WARD, M. H. 1882. Coffee leaf disease. Third report. Ceylon Planter's Association. Proceedings 1882:253-319.
- _____ 1882a. Researches on the life history of Hemileia vastatrix, the fungus of the "coffee - leaf disease". *Linnean Society. Journal (Botany)* 19:299-335.

- WATT, G. 1908. The commercial products of India. London, Murray. p. 363.
- + WATTENDORFF, F. L. 1901. Welke is de beste Koffiepulper? Indische Mercur 24(9):149.
- WEELE, H. W. van der. 1910. Ein neuer javanischer kaffeesch&mdling, Xyleborus coffeivorosus. nov. spec. Ind.-Neerland., Department of Agriculture Bulletin 35(5):1-6.
- WEL, A. R. van. 1938. Rationeel bodemonderhoud. Bergcultures 12(41):1396-1407.
- WELLENSIEK, S. J. 1934. Principes voor het selecteeren van moederboomen bij thee. Bergcultures 8(38):894-902.
- WERKMAN, J. W. 1936. Coupeeren van koffiebibit. Bergcultures 10(11):351-354.
- WESTER, P. J. 1916. Notes on coffee in Java. Philippine Agricultural Review 9:120-132, 150-152.
- + _____ 1920. Excelsa coffee in Trinidad. Philippine Agricultural Review 13:307, 368.
- _____ 1922. Graftage of coffee. Tropical Agriculturist (Ceylon) 58:63.
- + WHITE, C. TH. 1921. De aschgronden op de Kloethelling voor en na de eruptie van 1919. Indische Mercur 44(17):284.
- + WICHERS HOETH, A. W. 1937. Gedenkboek van de vereeniging voor den koffiehandel, 1887-1937. Amsterdam. pp. 99. 189.
- + WIGMAN, H. J. 1888. Liberia - koffie. Tijdschrift Landen Tuinbouw en Boschcultuur 3:3, 5, 8, 10.
- + _____ 1890. Liberia - koffie. Teysmannia 1:257-271.
- WILBAUX, R. 1937. Recherches préliminaires sur la préparation du café par voie humide. Institut National pour l'Etude Agronomique du Congo Belge (INEAC) Series Technique no. 13. 50 p.
- WILBRINK, W. G. J. 1939. Takent contra waaiertak; is verenting noodzakelijk? Bergcultures 13(27):933-937.
- WILDEMAN, E. de. 1901. Les caféiers. Bruxelles. 43 p.
- + _____ 1903. Plantae Laurentianae. Bruxelles. p. 35.
- + _____ 1904. Nouveaux caféiers de la Cote Occidentale d'Afrique. Agriculture Pratique des Pays Chauds 4:113, 116.
- + _____ 1905-1907. Mission Emile Laurent. Bruxelles. vol. 1. pp. 331, 337.
- _____ 1908. Les plantes tropicales de grande culture. Paris. 165 p. (Caféier, pp. 47-150).
- _____ 1910. Matériaux pour une étude botanico-agronomique du genre Coffea. Buitenzorg. Jardin Botanique. Annales (Supplement) 3(1):345-384.
- Wilson W. Mayne. See Mayne, Wilson W.
- + WOLK, van der. 1912. Bangelan en de toekomst der koffiecultuur. Teysmannia 23:374.
- + WURTH, TH. 1908. De boeboek (Xyleborus coffeae n. sp.) op Coffea robusta. Cultuurgids 10(3): 63.

WURTH, TH. 1908a. Heeft Coffea robusta een grooter weerstandsvermogen tegensiekten en plagen dan Coffea arabica en Coffea liberica? Verslag Algemeen - Proefstation te Salatiga, 1907. pp. 55-63.

- _____ 1909-1910. Onderzoekingen over Hemileia vastatrix Berk. et Br. (de koffie - bladziekte). Cultuurgids 11:539-547; 12:1-6. (Reprint Algemeen - Proefstation. Java te Salatiga Meded. 34-35 (Ser. 11):1-15. 1910).
- + _____ 1911. Het al of niet toppen van Coffea robusta. Cultuurgids 13:110.
- + _____ 1912. Degeneratie van Robusta - koffie? Malang Proefstation Mededeeling no. 4. pp. 10, 19.
- + _____ 1912a. Is de Quilloukoffie geschikt voor de sandgronden van den Kloet? Ned.-Ind. Landbouw Syndicaat Publicatie 4. pp. 344, 383.
- _____ 1915. Over koffie - hybriden. Ned.-Ind. Landbouw Syndicaat Publicatie 7(22):880-890.
- + _____ 1917. Toelichting op de eindconclusie van de Robusta - enquête. Ned.-Ind. Landbouw Syndicaat Publicatie 9. p. 341.
- _____ 1922. Over achteruitgaande Robusta - tuinen. Malang Proefstation Mededeeling no. 38. pp. 27-29.
- + _____ 1922a. Ter inleiding. Koffiebessenboek Fonds, Mededeeling no. 1. p. 1.
- + _____ 1922b. Tuin onderhoud en maatregelen tegen grondafspoeling bij de koffiecultuur. Verslag 2de Vergard. Vereen. Proefstation Person., 1921. p. 18.
- _____ 1922c. Een vuurwants (Dindymus rubiginosus F.), die jacht op de bessenboek maakt. Koffiebessenboek Fonds, Mededeeling no. 3. pp. 49-52.
- ZIMMERMANN, A. 1898. De nematoden der koffiewortels. I. Buitenzorg. 's Lands Plantentuin Mededeeling no. 27. 64 p.
- _____ 1900. De nematoden der koffiewortels. II. Buitenzorg. 's Lands Plantentuin, Mededeeling no. 37. pp. 1-23.
- + _____ 1900-1901. Eenige proeven en waarnemingen over aaltjes. Koffiegids 2:201.
- _____ 1901. Over het enten van koffie volgens de methode van den Heer D. Butin Schaap. Buitenzorg. 's Lands Plantentuin, Mededeeling no. 49. 54 p.
- + _____ 1901a. Verslag 3de Koffiecongres in Ned.-Ind., Malang, September 1900. Koffiegids 2. pp. 630, 632.
- _____ 1903. Einige bemerkungen zu dem aufsatz von F. Wohltmann über "Die aussichten des Kaffebaus in den usambarahe gen". Sand. Abdr., Ber. Land. u. Forstwirtsch. in Deutsch Ost - Afrika, 1, Hft. 5. p. 383.
- _____ 1904. Eenige pathologische en physiologische waarnemingen over koffie. Buitenzorg. 's Lands Plantentuin, Mededeeling no. 67. pp. 1-105.
- _____ 1928. Kaffee. Hamburg, Deutscher Auslandverlag Walter Bangert. 204 p. (Wohltmann - Bucher, Monographien sur Landwirtschaft warmer Lander. Band 4.)

INDEX

Note by the Editor:

This index has been prepared on the basis of subjects. Individual persons Dr. Cramer referred to are almost entirely represented in the names found in the literature list. It is impossible to know exactly how Cramer would have handled his subject indexing. I have attempted to make it rather detailed. This I hope will aid in the use of the text by the serious minded student.

Thinking of myself in the place of the one who wrote this collation of research notes, I have noticed the occurrence of old Dutch words included in certain well appreciated connections. In the main they have been indicated in the index, since for both practical and historical reasons they add much to the background of science as it pertains to coffee.

One of the difficulties in the indexing has been the problem of the scientific names of the coffees. It is well to point out that when he used a Latin binomial Cramer was well aware of the botanical implications in his field of coffee. This is shown in his discussions under his idea of "species", and especially of his "dynamic species", his "subspecies", his concepts of the "Linneon", and the "good species" in coffee.

Again it should be made clear that I have left the names of coffees as Cramer gave them. He used them as handles for known entities. These epithets meant, and still mean distinct materials, although some botanists might consider some of them only cultigens at most. Those of these named species to which Cramer gave the most attention have been indexed under a common name. This is not underlined, and is derived in the manner indicated by Cramer from the scientific denomination. This Latin name follows the common name, and is in parentheses. An example is Coffea abeokutae found indexed under Abeokutae. In Coffea canephora var. ugandae, known also as C. ugandae, the detailed indexing appears under Ugandae. Where a coffee is mentioned only a few times reference page numbers appear with the scientific name. — F. L. W.

- Abeokutae (Coffea abeokutae) 13, 109, 110, 142, 144, 147, 148, 150, 151, 156, 169, 170
Asikasso No. 19 coffee, 109
flavor superiority, 109-110
Gros Indénié, 109
Improved Liberica, 109
Ivory Coast, 109
origin, 109
proportion, 109
resistance to Rust, 109
species discussed, 109
yields, 109
- Abyssinia
country of origin of coffee, 5
home of C. arabica, 89
- Abyssinian coffee, 73, 104
selection for Java, 104
- Acacia decurrens, 57
A. multijuga, 87
- Adjowtoel weed control, 23
- Adulterants of coffee, beans, 173
chicory, 172
corn, 172
horse liver baked, 173
katjang, 173
Leucaena glauca, 173
ox liver baked, 173
parchment of coffee, 172
rice, 172
silver skin of coffee, 172
skin of berry (cherry), 172
tree seeds, 172
- Aged coffee, preference for, 165
- Ageratum conyzoides, 24, 25
A. mexicanum, 24, 25
- Albizia (shade), 56-57, 82-83
advantages in use, 83
disadvantages, 82-83
disease of, 83
extracts lime from soil, 83
soil improved by, 83
- Albizia falcata, 27, 80, 83
A. fastigata, 80
A. leboeck, 80
A. malacocarpa, 83
A. moluccana, 83
A. montana, 83
A. stimulata, 80, 83
A. sumatrana, 83
- Alcoholic liquor from coffee, 175
- Algae, 48
- Alkaloid caffeine (see: caffeine), 6
- Altitude, and coffee, 79
Congusta requirements, 158
effect on Rust, 79, 103
fertilizers at different altitudes, 23
Liberica requirements, 106
optimum for certain species, 79
planting and altitude, 158
Robusta requirements, 19, 113-114
Arabica at sea-level, 79

- Amaranthus spinosus, 24
Amsterdam Botanical Garden 5
Ankola coffee (Java), 166
Annual crops following coffee, 8
Antilles, Lesser, introduction, 5
Ants, control with traps, 55-56
Anguillulina pratensis, 50
A. similis, 50
Apis indica, 61
A. mellifica, 61
Arabia (the country) in history of coffee, 7
Arabian coffee (see Arabica), 20
Arabica (Coffea arabica) 2, 9, 18, 19, 21, 23, 114, 116, 135-198, 141, 142, 146-155, 159-160, 163, 165-166, 168-170, 175, 177-179
varieties of, 95-100
Abyssinian, 73, 89, 102, 104, 160
affinis (see C. affinis), origin, 136
amarella, amarelo, 98, 100, 147, 151
angustifolia, 95, 97, 148, 151, 153
anomala, 100
arila, 150, 151, 160, 161
Blue mountain, 100, 102
Botucatu, 98
bourbon, 90, 100-102, 147-149, 151, 161, 162
Bourbon amarelo, 100
Bourbon pointu, 96
bourbon x canephora, 151
Bronze tip, 90
bullata, 95, 97, bud sports, 148
Cafe commun (Brasil), 90
calycanthema, 100
cera, 6, 100
columnaris, 99, 100, 102
Djamboe type, 149
erecta, 98, 100, 102, 148, 151
goiaba, 148, 151
Guatemala, 100, 102
Harrar, 89
intermedia, 91, 138
Jackson, 100, 102, 103
Java, 89, 171
Kabare, 100, 102
Kent, 98, 102
Kenya, 90
Kissegnies, 102
laurina, 96, 101, 147, 151, 162
Leroy, 96
Local Bronze, 102
Loss, 90
maragogipe, 98-101, 147, 150-153, 159-162, 169
Mbirizi, 100, 102
Mayaguez, 102
Menado, 154
mokka (or mocha), 95, 100, 101, 148, 151, 161, 162
Mokka, large bean, 162
Mokka, small bean, 169
monosperma, 97, 148, 149
murta, 96, 148, 151
Mysore, 102
Nacional, 90, 100, 101, 147, 151, 162

- nana, 96, 100
- Padang, 100
- pascamah, 102, 103, 160
- pendula, 98
- polysperma, 97, 148, 149, 151
- purpurascens, 95, 98, 148, 151
- San Ramon, 96, 97, 100, 162
- San Ramon Mineatura, 102
- Santiago, 102
- semperflorens, 100, 150
- small leaved, 95
- stuhlmanni, 121
- Sumatra, 100
- tetramera, 100
- typica, 95, 97, 149, 162
- variegata, 98
- West Indian or Puerto Rican, 99
- yellow fruited, 90, 98, 100
- Arabica coffee (see "Arabica" above)
- allopolyploid, 150
- altitude relations, 38, 89-90, 103
- belts for growth of, 103
- botany of, 6-7
- Brasil introduced, 100
- cafféine content, 169
- chromosomes in, 148
- closely allied species, 90
- cross with C. mauritiana, 96
- degeneration problem, 91-94, 102-103
- descent of Arabica from C. arabica var. erecta, 98
- descent of Arabica from C. canephora, 150
- description of 7, 89
- dihaploids in, 150
- divergent types, 90
- endosperm of, 6
- first commercial species, 6
- genetics of "Bronze tip", 102
- genetics of varieties, 96, 97, 98
- grafting, 159
- homogeneity in Arabica, 102-103
- hybrid, 103
- improved, 102
- indigenous occurrence, 7, 89
- individual differences, 102
- irrigated in Abyssinia, 89
- multitudes of forms wild in Abyssinia, 142
- native plantings, 178
- natural state, 89
- naturalized occurrence, 7
- plantings converted to Hevea, 114
- plantings, distances in Java, 18
- pollinated with C. excelsa and C. liberica, 6
- polyploids, 148, 150
- production in Amazon Basin, 79
- production in the world, 177
- pruning for rejuvenation, 93
- pruning for the undertree, 20
- quality in, 165
- reintroduction from Abyssinia, 92-93
- replacement with Robusta (Indonesia), 114

resistant to *Cercospora*, 104
resistant to Rust, 104, 142
selection, 92, 100-102
soils for, 103
stocks for grafting, 159
tetraploids, 150
topping, 19, 20
tree description, 6
types numerous selected, 102
uniformity trials, 101
variable forms recognisable in Africa, 104, 142
variation in buds, 96, 149
varieties, genetics of, 97-98
variety hybrids, 101
water culture studies, 23
wild collection by Cramer, 144
wild state of Arabica, 89
wild varieties, 89, 142
yield, 91, 92, 101
yield and weather, 91
Arabs, their use of coffee, 5
Araucerus sp., 165
Aroma (see: quality, taste and flavor)
 blending for, 171
 deterioration, 172
 differences in clones, 171
 olfactometric measurement, 170
 Osmoscope, 170
 production of, 172
 Robusta, 113
 synthetic, 171
Asikasso coffee, 109
Autofecundation, 60

Bacterium lactis aerogenes, 34

Bali, 8
Batard (bastard) coffee, 140
Beans, of coffee (see: market product)
 abnormal rejected for planting, 16
 aged, moisture relation, 165
 aged, preference for, 165
 altitude grown and size, 166
 ash of, 172-173
 black, 37, 167-168
 borer damage, 166-167
 caffeine, content of, 168-170, extraction of, 174-175
 caffeel in, 171-172
 caffetamic acid in, 172
 classified in field processing, 36-37
 color change, heat and chemicals, 35, 165
 color, market requirement, 167
 combustible, use for, 175
 damage by Stephanoderes, 166-167
 dark, 168
 defective, 61
 descriptions, Arabica and Robusta, 166
 drying of, 154
 elephant (size), 62
 empty, 61

Excelsa, 111
external condition effects, 128
fat content in, 171
flavor deterioration in, 172
flavor types, prices for, 107
grinding, 171
hulled by hand, 167
Java Blue, 165-166
Java, spongy, 171
Kried bean, 166-167
larger from crosses, 163
Liberica type, 107
odor change in, 165
pea berry, 61-62
polishing of, 36
pulverizing for infusion, 173
Robusta type, 113
roast of, 171
roast, changes from, 171-172
roast, change in caffeine content, 172
roast, cleaning and mixing for, 171
roast, dull, 172
roast, flavor loss after storage, 172
roast, volume increase from, 172
roast, weight losses from, 171-172
roasted bean, exported from Java, 172
round bean for planting, 16
shape, irregular, 135
shrivelled, 61
silverskin of, 6
size in clones, 133
size, conditions effecting, 166-167
size, hereditary, 159, 163, 170
size problem, 128
skins, use of, 174-175
speckled, 167
Stenophylla, 135
stink coffee, 166
substitutes for beans, other parts of plant, 174-176
taste, musty, 165
used for fertilizer, 175
volume, change in roasting, 171
voosboon, 61
weevil, 165
white bean or witboon, 34
yellow color of, 107, 113, 159
Bees and pollination, 61
Berries (cherries), color of, 135
surrounded with stipulae, 121
use of their skins, 33
Berry Borer (see Stephanoderes hampel), 33, 41, 51-54, 101
in seed, turpentine treatment, 17
parasites introduced for, 14
resistance to in Dybowski, 111
severe in Congustas, 158
Bessenboekhoek, 51-54
Beverage coffee, making of, 173
Biennial bearing, data on, 101
Blending, in manufacture, 171
Blue Mountain coffee, 100, 102

Boemboeng, trap for ants, 55
Bogor Prada Hybrid coffee, 159
Boon, Kried, 166-167
Books, general on coffee, 2-3
Bordeaux Mixture, 49, 83
Borers, branch, 41, 54-55
Borers, branch of shade trees, 55
Borer, resistance, 14
Botanical coffees, 139-140
Botanical studies on coffee, 6
Botrytis stephanoderes, 53
Botucatu coffee, 98
Bourbon coffee, 90, 101
Bourbon, island of (Reunion), introduction of coffee, 5
Bourbon Ordinaire coffee, 102
Brachytrupes protentosus, 57
Branch, orthotropic type, 70
Branch Borer, resistance in Congusta, 159
Branch Borer, black, 20
Brazil, coffee introduction, 5-6
Brazil, competition with Indonesia, 7
Brazil, manuring rotation in, 27
Breeding (see Crosses, Hybrid, Chromosomes, etc.)
 bean size, 163, 170
 caffeine content, 170
 chromosome problem, 147, 152
 Hemileia Rust resistance, 152
 results from, 149
 sterility in haploids, 149
Briquettes from berry skins, 33
Budding, shield, 64
Buds, adventive, 71
 auxiliar, 71
 axillary, 72
 legitimate, 70
 primary reproduction, 70
 serial, 19, 70-72
 sports, 148
Budwood, 70
Buitenzorg, 9, 10, 12
Bukobensis coffee, 150
By products of coffee, 174-175

Caconema raditicola, 50
Caesalpinia dasyrachis, 87
Cafamarine flavor substance, 169
Cafe a la sultane, 175
Caffeine, 6, 168-170
 amount in coffee, 176
 coffees from different areas, 169
 commercial sources, 174
 content in beans, variation between trees, 169
 content change by roast, 172
 content from pulverized coffee, 173
 content, hereditary, 160, 170
 content, high in instances, 169-170
 content in standard market coffees, 169-170
 content in tree parts, 6
 content unrelated to taste, 168-169

- description of chemical, 174
- extraction from skins, 175
- extraction from tea, 174
- extraction method, 174
- percentage of in certain species, 6
- removal treatments, 174
- species without, 6
- Caffeine-free coffee, by chemical methods, 174
- patents for making, 174
- wild species, 169
- Caffetannic acid, 172
- Calcium, 83
- Canavalia ensiformis, 27
- Canephora (Coffea canephora, also see, Robusta) 1, 2, 13, 117, 120, 123, 125, 126, 137, 138, 144, 147, 148, 150, 151, 156, 157, 161, 163, 169, 170, 178
 - ancestor of C. arabica, 150
 - caffeine content high in, 169
 - clone for graft, 120
 - clones of, 125
 - drought resistance, 120
 - Hemileia, varying susceptibility to, 120
 - history and introduction, 120
 - indigenous growth and origin, 120
 - variety bronze leg, 120
 - var. hiernii, 106, 120
 - var. kouillouensis, 1, 106, 120, 156, 157
 - var. kwiluensis, 1, 13, 120, 163
 - var. quillou (see Quillou)
 - var. robusta (see Robusta) 1, 2, 152
 - var. sankuruensis, 13
 - var. ugandae, 1, 152
 - variety yellow fruited, 98
- Canthium campanulatum, 42
- Capnodium javanicum, 48
- Cassia florida, 81
- Castilleja elastica, 87, 141
- Catch crop, coffee as, 179, 180
- Cayenne, coffee in, 5
- Cazengo coffee, 116
- Cedrela odorata, 87
- C. serrulata, 87
- Celebes, coffee in, 8
- Cellulose in coffee, 176
- Central America, coffee in, 5
- Centrosema toxicity, 25
- Cephaleuros coffeae, 48
- Ceratophorum albissiae, 83
- Cercospora coffeicola, 48, 104
- Cherry, see Berry
 - size large as plums, 111
- Chewing of green coffee berries, 175
- Chick coffee, 102
- Chicory, 172
- Chimera, occurrence of, 150
- Chirinda coffee, 136
- Chromosomes, allopolyploid, 150
 - aneuploids, 149-152
 - Arabica, 116
 - colchicine studies, 148-149
 - counts and leaf stomata, 149-150

- crosses between divergent types, 143
 - crosses, predominance of character from larger number, 160
 - cytology of, 147-152
 - different sizes in Excelsa, 151
 - dihaploid, 150
 - diploid, 147-152, 154, 160
 - Djamboe type, 149
 - doubling in, 148
 - Excelsa groups, 151
 - extra, 151
 - fragments of, 149, 151
 - growth effects, 147-148
 - growth of mixochimeras, 148
 - growth rates from, 147-148, 152
 - haploid, 147, 149, 151-152
 - haploid in Arabica, 160
 - hexaploid, 148
 - lengths differing, 147
 - Liberica, 116
 - meiosis, 148, 150-151
 - microsporogenesis, 149
 - monosperma, 149
 - morphology of, 148, 150
 - numbers of, 147, 150
 - numbers and fruit set, 150
 - numbers, basic, 150
 - numbers reduced, 149
 - numbers, tables of, 147, 151-152
 - octaploid, 148, 151
 - polyploid, 148, 150
 - polysperma, 149
 - prochromosomes, 147
 - reaction at meiosis, 148
 - Robusta, 116
 - rough tetraploids, 148
 - sizes in Excelsa, 151
 - somatic, 147, 148
 - stomatal areas affected by chromosomes, 150
 - study of, 147
 - tetraploid, 143, 147-152, 154, 160
 - triploid, 147, 150-152, 161
 - variable, 149
 - vegetative reversions in, 148
 - yield related to, 152
- Cinchona, 26
- Climate, 103, 113, 114
- Clonal, plantings, advantages, 67-68
- Clones, 14, 18, 128-134
- aroma differences in, 171
 - bean size in, 133, 170
 - better than seedlings, 67-68, 123
 - Bgn 124, origin, 144
 - branch graft, 133
 - Congusta, 133, 159
 - cutting source, 75
 - cytology in, 150
 - diclonal fields, 131
 - Excelsa, 10
 - grafting, 162-163
 - harvest period differences, 67

large bean, 163
mixed for cross pollination, 159
monoclonal fields, 131
museum of, 124
names old and new, 133
rejuvenation by, 133
resistant to Berry Borer, 14
Robusta, 10
Robusta Bgn 124.01, history of, 162-163
Robusta, chromosome counts in, 150
Robusta SA.109, history of, 163
Robustoid, best of, 133
seedling family relations, 130-132
selection, 132
special, history of, 134
study of chromosomes in, 147-152
uniformity in, 64
universal, 132-133

Cloranth (see Virescence, Star flower)

Coccus viridis, 55

C. hemisphaericum, 55

C. hemisphericus, 55

Cocoa, 170

Coefficient of superiority, 125

COFFEA

C. affinis, 136, 156

C. arnoldiana, 13, 109

C. aruwimensis, 14, 109

C. bengalensis, 7

C. brevipes, 14

C. brevipes var. longifolia, 138

C. bukobensis, 14, 121

C. congesta (see Congusta)

C. dewevrei, 13, 100, 109, 148-151

C. dewildemann, 106

C. dubardi, 169

C. dybowskii, 14, 110-111, 139, 148, 150-151, 162

C. eugenioides, 14, 91, 95, 138-139, 142-144

C. excelsa (see Excelsa)

C. gallienii, 139

C. horsfeldiana, 7, 143, 150, 152

C. humblotiana, 169

C. humilis, 14, 140, 143

C. intermedia, 138

C. kivuensis, 90, 141

C. klainii, 111

C. lancifolia, 169

C. laurentii, 12, 119, 147, 150, 160

C. liberica (see Liberica)

C. maclaudii, 121

C. macrochlamys, 111

C. madurensis, 7

C. mauritiana, 96, 137, 140, 169

C. microcarpa, 95

C. ocymensis, 111

C. pierrei, 169

C. quillou (see Quillou)

C. robusta (see Robusta)

C. salvatrix, 14, 146

- C. schumanniana, 14, 139-140
- C. semiexperta, 147
- C. sp. Lamorary, 111
- C. stenophylla (see Stenophylla)
- C. swynnertonii, 136
- C. togocensis, 136
- C. ugandae (see Ugandae)
- C. van roecheoudtii, 90, 141
- C. sanguebariae, 139
- Coffee, crisis, 7
 - fund, qualities defined by, 168
 - rat, 7, 33, 51
 - species material in, 13-14, 141
- Coffeol, 171-172
- Colchicine, use of in breeding, 148-149
- Colombian coffee, 171
- Colletotrichum incarnatum, 48
- Color of bean, 6
- Combined coffee and rubber in field, 114-116
- Commercial differences, individual Robustas, 170
- Commercial product, first C. arabica, 6
 - parchment and silver skin used, 174
 - (see Bean)
- Common coffee, Brazil, 90
- Compost from coffee skins, 22
 - studies in, 23
- Congensis (C. congensis) 13, 91, 95, 120, 136-138, 141-144, 147-148, 150-153, 156-157
 - description, 136-137, 156
 - flavor, 137
 - for high altitudes, 157
 - forms, numerous, 142
 - grafts, 137
 - habitat, 142
 - hybrids, 13, 157-158
 - occurrence and origin, 136-138
 - resistance to Hemileia, 136
 - root system weak, 142
 - time of harvest, 137
 - yield, 137
 - var. chaletii, 13, 137, 156-157
 - var. frechmeri, 137
 - var. Madagascar, 157
 - var. eubanghiensis, 137
 - var. subsessilis, 137
- Congusta (C. congensis crossed with C. robusta), 69, 103, 124, 126, 130, 133, 137, 144, 150, 157-159, 163, 178
 - beans of, 158-159
 - description of, 158-159
 - grafting of, 69
 - hybrids and clones, 103, 124, 126, 130, 133, 157-159
 - planting distances, 158-159
 - proportion, 158-159
 - quality, 158
 - resistance to branch Borer and drought, 158
 - resistance to Hemileia, 103, 158
 - susceptible to Berry Borer, 158
 - topping (pruning), 158
 - yields, 158
- Consumption of coffee locally in Indonesia, 178-179
- Conga (see Congusta) 124, 137, 150, 157-158, 178

- Corticium salmonicolor, 48
Cocoa coffee, 62
Cover crops (also see Green manurers), 23, 145
 auxiliary type, 24
 innocuous, 24
 roots with toxic excretions, 24, 26
Cramer on:
 branches and buds, 70-72
 degeneration problem, 122-124
 humus importance, 27
 fundamentals of improvement, 10
 Congensis hybrids, 156-157
 hybridization in coffee, relative ease, 143
 importance of new species, 8
 plant collecting, 144-145
 search for resistant types, 145-146
 species that are good in coffee, 141-143
 variability in wild coffee, 144
 wild arabica collection, 144
Cricket, Indian, 57-58
Crisis, Coffee market, 166
Crop, auxiliary, 26
Crop of coffee, growing of, 77-79
 on estates, 29
 variation in, 178
Crosses (see Hybrids, Breeding)
 Arabica & Liberica, 143-147, 153
 Arabica & Congusta, 143, 146
 Arabica & Laurina, 151
 Arabica & Robusta, 143, 146
 artificial method, 163
 bean size studies, 128, 163
 between Robusta types, 125
 between subspecies, 162-164
 Canephora & Ugandae, 144
 chromosome numbers and, 143
 chromosome types used - octoploid & tetraploid, 148
 chromosome types used - tetraploid & octoploid, 148
 chromosome types used - triploids, 148
 Congensis & Robustas, 144
 ease of making, 147
 Excelsa & Liberica, 144
 for large beans, 163
 interspecific, 153-164
 Liberica & Abeokuta, 144
 mother plant influence, 153
 problems of, 143
 reciprocal, 143
 Robusta & Excelsa QP, 152
 Robusta & Liberica, 143
 Robusta & Maragogipe, 143
 Robusta & Quillou, 144
 Stenophylla & Libericas, 143
 using Congustas, 159
Crotalaria, 24
Crotalaria anagyroides, 26, 78
C. juncea, 27
C. usaramoensis, 26
Cuba, coffee introduction to, 5
Curing of coffee, 33, 35, 107, 168

- difficulties with Liberica, 35
- dry process or East Indian, 39
- faults in, darkened beans, 168
- problems in, 39, 107, 168
- wet process or West Indian, 33
- Cuttings in coffee
 - Arabica, auxins and ringing, 74
 - Arabica, conditions for rooting, 74, 75
 - Arabica, rooting cases, 75
 - Arabica, sunlight relation, 74
 - Arabica, type of wood, 75
 - Arabica, under glass, 74
 - Liberica, type of wood, 74
 - necessity for leaves, 74
 - orthotropic, 75
 - potting of, 74
 - Robusta, basal cut, 75
 - Robusta, planting in cases, 74
 - Robusta, suitable material, 74
 - root development, 75
- Cynodon dactylon, 24
- Cytology (see Chromosomes, Crosses, Coffea, Coffee varieties), 147-152
 - evidence C. arabica ancestry was C. canephora, 150
 - nuclei in endosperm, 150
 - pollen mother cells, 144

- Dadap, 8, 23, 27, 57, 80, 81, 82
 - fly on, 82
 - friend of coffee, 82
 - insect attack, 82
 - serep, 82
- Dedek (broken parchment), 165
- Deficiencies of chemicals in coffee, 21-23
- Degeneration of coffees, 3, 91, 92, 108, 122
- Dequelia microphylla, 87
- Department of Agriculture, 13
- Desmodium gyroides, 26
- D. ovalifolium, 26
- Destruction of market coffee, 175-177
- Dieback, 48, 101, 159, 162
- Dindymus rubiginosus, 53
- Disease, 9, 30, 41, 48-49, 58, 62, 99, 104, 145
 - Cercospora leaf spot, 104
 - control of costly, 145
 - fruit shedding, 30
 - leaf (see Hemileia), 41
 - other fungoid, 48
 - root, 49
 - phloem necrosis, 58
 - Polyporus, 49
 - top, 49
- Distribution of coffee, 5
- Djamboe coffee, 149
- Djombret, weed control system, 24
- Dompolan lice, 56-57, 85, 88, 158
- Drought, effects from 78
 - resistance in Excelsa, 111
 - resistance in hybrid, 156

- Drying beans, curing process, 36, 37, 39, 159
 - floors over fire, 36
 - glass hard, 36
 - killing by heat, 36
 - problems of, 39, 159
 - rake-carrier dryer, 36
 - special houses for, 36
 - temperatures, 35
 - time required, 36
 - turret dryer, 36
- Drymaria cordata, 24-25
- Dutch East India Company, 5
- Dutch East Indies Forest Service, 8
- Dutch influence in history of coffee, 5
- Dutch merchants and coffee, 5

- East India Company, 7
- East Indian cure, 39
- Embryo sac development, 61
- Empusa resenii, 56
- Endocarp of fruit, 6
- Endosperm, 6, 150
- Enzymes, 35, 165
- Erosion control, 18, 27
- Erythrina, 23, 27, 81, 82
- E. crassifolia, 82
- E. excelsa, 82
- E. lithosperma, 27
- E. lithosperma var. inermis, 27, 81
- E. micropteryx, 82
- E. poeppingiana, 82
- E. subumbrans, 27
- Erythrina, thornless, 82
- E. variegata var. orientalis, 82
- E. velutina, 82
- Estate coffee industry in Java, 8
- Ethylene gas to ripen seed, 17
- Eupatorium inulifolium, 25
- European coffee history, 5
- Excelsa (Coffea excelsa), 2, 6, 10, 13, 18, 24, 100-111, 139, 142, 144, 147, 150-155, 159, 162, 170
 - adaptability wide, 110, 111
 - beans of, 111
 - chromosome characters, 151
 - clones, 10
 - clone selections, 111
 - description, 109, 110, 111, 142, 151
 - discovery of, 110
 - distinctions from Liberica, 142, 150, 151
 - drought resistance, 111
 - Excelsa du Mayombe, 111
 - economic importance, 109
 - flowering of, 111
 - grafting, 159
 - in Africa, 110
 - in Brazil, 110
 - in Trinidad, 110
 - market preference, 111
 - origin, 110
 - planting distances, 18

- proportion, 110
- resistance to frost, 110
- resistance to Xylotrechus, 110
- root system, 111
- strains Excelsa 1 & Excelsa 4, 162
- transitional species with Liberica, 109
- yields, 111
- Excesses of chemicals, studies on, 22
- Exportation of coffee from Indonesia, 178-179
- Extirpation policy, 7

- Following to destroy nematodes, 18
- Fan branches, 71
- Fan grafts, 69
- F. A. Q., Fair Average Quality, 37, 128, 166, 167
- Fasciation, 62
- Fermentation, and taste, 34
 - bacterial, 34
 - bad odor from, 35
 - Congusta, 158
 - early use in Java, 39
 - enzymatic, 34
 - not necessary, 34
 - purpose of, 34
 - time for, 34
 - treatments to eliminate, 34
 - yeast, 34
- Ferrisia virgata, 57
- Fertilizer made from beans, 175
- Fertilizing, artificial manures, 21, 25
 - at different altitudes, 23
 - chemical-organic, 23, 27
 - chemicals with mulch, 25
 - effective, 25
 - green manures, 23
 - offal used for, 23
 - old coffee, 9, 21
 - studies of, 21-23
 - young coffee, 21-22
- Ficus, 141
- Fields, monoclonal, 131
- Fire wood from shade, 84, 86
- Flavor (see different coffees, quality, taste)
 - best from filtered infusion, 173
 - bitter & woody, 173
 - loss of in stored roasted bean, 172
 - measurement, standard cup method, 170
- Flowering, 8
 - and altitude, 29
 - and crop, 30-31
 - buds used in grafting, 72
 - estimate of crop from, 29-30
 - grafted wood, 66
 - graft influence on, 69
 - hybrids, 153
 - number of flowers per tree, 29
 - physiology of, 24
 - types of, 30
 - water requirements in, 29

Flowers, abnormal or abortive, cloranthy, 32, 107, 117
in Excelsa, 111
essential oil from, 176
formation seasonal, 59
star flower 32, 117
virescent, 32, 107, 117

Fomes lamoensis, 49

F. noxius, 49

Forest, destruction of, 8

Forest, hydrologic, 38

Forest, soils for planting coffee, 8

Forest Service in Dutch East Indies, 8

France, coffee beverage introduced, 5

Frost resistance in Excelsa, 110

Frost resistance in Murta, 96

Frosts, shade protection from, 78

Fruits (cherry, see berry)

color bronze and brown, 120

color yellow, 116

drop of, 160

endocarp in, 6

held on branches, 155

parts of, 6

pericarp, 6

polyembryony, false, 116

polyspermy, 116

set, chromosome number and, 150

set in hybrids, 153

shedding, 30, 160

unripe cause of dark beans, 168

Grangair, 57

G. B. or Gewone Bereiding (dry cure), 39, 167

Genetics (see breeding, chromosomes, crosses, hybrids)

Glirescencia maculata, 87

Gloeosporium coffeanum, 48

Government aid to producers, 168

Grafting, 63-74

advantages of, 67

approach, 64

Arabica on Excelsa, 69

Arabica on Horsfieldiana, 69

Arabica on Liberica, 63-65

branch, fan and whip, 61, 71, 133

Butin Schaap method, 66-67

cleft, 64-66

Coffea on Periploca, 14

Columnaris stock for, 102

compared with seedlings, 64

Congusta on Excelsa, 156

Congusta on Robusta, 156, 158

cuttings, 74

conversion by, 20

direct relation to mother tree, 132

Erecta, 65

Eugenioides, 66

Excelsa, 68-69, 156

extensive field application, 64, 65, 71-73

flower buds used in, 72

- growth influenced, 71
- history of, 63, 154
- Horsfieldiana, 69
- hybrids, 66-68, 154
- hypocotyl method, 66
- imperfect union in, 64
- increase in production by, 18
- influence of tree vigor on, 69
- in Philippines, 73
- Ixora, 69
- Kawasari, 68
- Liberica, 65
- Liberica on Excelsa, 69
- Maragogipe, 64-65
- Mokka, 65
- nursery method, 69
- overbearing reduced by, 68
- pretreatment for, 69-72
- production robe, 18
- purpose of, 72, 154
- Quillou, 69, 72
- radical, 73, 74
- rejuvenation by, 71-73, 159
- replacement of poor yielders by, 18
- Robusta and Excelsa, 64, 68-69
- Robusta on Robusta, 68
- root and double root method, 64-66
- routine system, 63
- Rubiaceae not coffees, 66-69
- selected clones, 120, 125, 128
- selective, 73-74
- shade trees, 85
- special clones for, 67-73, 111, 158, 162-163
- sprouting time after, 73
- stock problem, 68
- study of, 10, 64, 68
- stump, 20
- top, 74
- tube, 64, 66
- tube, use of glass, 66
- tube, use of paper, 66
- Typica (C. arabica), 65
- under glass house, 63
- use of proven clones, 20-21
- wax simplification, 66
- whip branch use, 63-70
- wood for sciens, 70-71
- yield studies, 71-73, 129
- wood, plagiotropic, 70
- Gramang ant, 55
- Grass, control, 23, 83-84
 - following forest, 8
 - harmful effects of, 24
 - noxious, 25
 - shade for control, 83-84
- Green color of beans, 167
- Green manurers (see Ceber crops), auxiliary, 24
 - berry borers effected by, 26
 - bushy, 24-26, 87
 - carpet formers, 24
 - erect control by, 26

- Indigoferas, 26, 86
- Leucaena glauca, 25
- organic matter produced by, 26-27
- susceptible to Mealybug, 56
- Green scale (see Coccus viridis), 41
- counter measures, 55-56
- Grevillea robusta, 78, 87
- Gros Indenie coffee, 109, 156
- Group hybrids, see Hybrids
- Growth, branch potency in, 71
 - bud arrangements effect, 70
 - crow's nest type, 70
 - fan branch, 71
 - influence in top by graft, 69-71
 - lateral and shoot differences, 72
 - legitimate branch, 71
 - primary branch, 70
 - rejuvenation of, 73
 - reproduction branch, 71
 - secondary branch, 71
 - suckers, 70
 - tertiary branch, 71
 - whip branches, 70-71
- Guinea, naturalised Arabica in, 7
- Guttapercha, 10

- Harrar coffee, 89
- Harvest, in Arabica, Liberica, Robusta, 32
 - coffee rat excrement, 33
 - dry berries, 33
 - native, 39
 - premature, effects from, 39
 - ripening in monoclonal plantings, 67
 - timing by use of clones, 67
 - uniformity in monoclonal plantings, 67
- Helicobasidium, 49
- Hemileia canthii, 41
- Hemileia rust (Hemileia vastatrix) 2, 7-9, 41, 104, 122, 145
 - adaptation to field from wild, 42
 - altitude effect, 79, 103, 155
 - attack of leaves, bark, fruit, 44
 - disaster in Ceylon, 41-43
 - discovery in Indonesia, 41
 - effects on yield, 41-43, 91
 - factors increasing severity, 43
 - grafting for control, 63
 - history of spread, various countries, 41-42, 145, 177
 - hybrids, reactions to, 46-47, 103, 122, 146, 154-158, 160-161
 - immunity, Arabicas from country of origin, 91, 142, 146
 - immunity, practical in hybrids, 146
 - immunity, Kalimas hybrid, 146
 - introduction not with Liberica, 42
 - Java, first appearance in, 145
 - on C. arabica, 43-44
 - on C. bengalensis, 42
 - on C. congensis, 46
 - on C. liberica, 43-44, 106
 - on C. madurensis, 42
 - on C. mauritiana, 41

- on C. mokka, 41
- on C. perrieri, 46
- on C. robusta, 114, 122
- on C. schumanniana, 46
- on C. travancorensis, 42
- origin of, 42
- physiological strains in, 43
- resistance to, 12, 14, 41-46, 92, 96, 102, 106-111, 135-136, 192, 146, 160-161, 154-158
- resistance to in clones, 45
- resistance to in Arla, 160
- resistance to in C. abeokuta, 45, 109
- resistance to in C. arabica, wild, 142
- resistance to in C. arabica x C. congensis, 161
- resistance to in C. congensis, 46, 136
- resistance to in C. congensis var. chalogii, 157
- resistance to in C. dybawskii, 111
- resistance to in C. laurina, 96
- resistance to in C. liberica, 12, 41, 106-108
- resistance to in C. salvatrix, 14, 146
- resistance to in C. ugandae, 46
- resistance to in C. stenophylla, 46, 135-136
- resistance to in C. stenophylla x C. abeokuta, 156
- resistance to in Congusta hybrids, 103, 158
- resistance to in Kalimas hybrid, 154
- resistance to in Kawisari hybrid, 155
- resistance to in Kents, 102
- resistance to in Robusta-Arabica hybrids, 160
- Robusta resistant coffee replaced Arabica, 43
- selections against, in Excelsa, 111
- severity in general in Indonesia, 41
- soil relation, 103
- spread (see history) 41
- stem forming graft effects, 70
- susceptibility to in Arabica, 41-44, 91, 95, 143
- susceptibility to in Canephora, 45, 125
- susceptibility to in Eugenioides, 138
- susceptibility to in Excelsa, 45
- tolerance in Robusta, 45
- tolerance in wild coffees, 42
- virulence, increase in, 45-46
- Herlin coffee (café Herlin), 99
- Heterodera marioni, 50
 - on both Arabica and Robusta, 50
- Hevea (rubber), 114-115, 129, 141, 144
 - clones adapted for growing with coffee, 115
 - interplanted with Arabica, 115
 - interplanted with Robusta, 114-115
 - to replant old Arabica fields, 114
 - wild collection, 144
- High altitudes, hybrids adapted to, 157
- Highland coffee (special name), 135
- History of coffee, early, 5
- Holland, coffee fund of, 168
 - coffee plants in, 5
 - colonial coffee, 5
 - tax in, to aid producers, 168
- Helotrichia leucephthalma, 57
- Humus, content reduced in soil, 145
 - importance for coffee, 27

- loss of in soil compensated for, 145
- on soil, value of, 145
- waste of danger, 27
- Hybrids (see Crosses, Breeding, Genetics), 3, 9, 10, 103, 120-125, 136-139, 143-148, 150-164, 170
 - Arabica, 3, 10, 143, 147-155, 160-163
 - Arabica x Canephora, 147-148
 - Arabica x Congensis, 147, 161
 - Arabica x Laurentii (Arla), 150, 160-161
 - Arabica x Liberica, 148, 151-155
 - Arabica x Liberica x Arabica (Maragogipe), 153
 - Arabica x Robusta, 147, 159, 161-163
 - between distinct species, 153
 - between varieties, 162-164
 - caffeine study, 170
 - Canephora x Congensis, 120
 - chromosome counts in, 147-148
 - C. affinis considered hybrid, 156
 - C. canephora var. kouilouensis considered hybrid, 156
 - Congensis x Canephora, 156, 159
 - Congensis x Robusta, 156
 - Congensis x Stenophylla, 153
 - Congensis x Ugandae, 153-157
 - Cong. sta, 10, 124, 157-158
 - Congusta and Conuga, 124
 - difficult to make, 151
 - diploid, 143
 - Excelsa x Liberica, 144, 162
 - generative production, 153
 - grafting of, 154
 - groupings (see under Coffea, Breeding, Crosses)
 - group of Congensis, 157-158
 - history of work, 153
 - Horsfieldiana x Robusta, 143
 - improving quality: Congusta x Arabica, 163
 - intergeneric, 143
 - interspecific, 146, 151, 153, 159-160, 163
 - intra group, 163
 - Kalimas, 3, 146, 153-155
 - Kapakata x Canephora, 161
 - Kapakata x Robusta, 161
 - Kapakata used with coffees, 139, 161, 163
 - Kawisari, 3, 146, 153-155
 - large scale production of, 163
 - Liberica, 10
 - Liberica x Abeokuta, 144
 - Liberica x Arabica, 153, 155, 162-163
 - Maragogipe (Arabica) x Robusta, 159-160
 - mother plant influence, 153
 - problem of, 163
 - QP hybrids, 143, 155-156
 - readily secured, 121, 147, 153, 156
 - Robusta considered a hybrid, 151
 - Robusta x Arabica, 143, 159-160
 - Robusta x Arabica x Arabica, 160
 - Robusta x Excelsa, 150, 155
 - Robusta x Liberoids, 153, 155
 - Robusta x Maragogipe (Arabica), 143
 - Robusta x Quillou, 162-163
 - second generation, 153
 - seed failures, 153

seedling variability in, 157, 163
Soember Sengkareng, 155
Soember Telogo, 155
spontaneous, 136, 138, 143, 154, 160, 162
spontaneous, Dybowski x Liberica, 162
spontaneous, Liberica x Arabica, 154
spontaneous, Robusta x Arabica, 160
spontaneous, Stenophylla x Liberica, 136
Stenophylla, 157
Stenophylla x Abeokutae, 156
Stenophylla x Liberica (Gros Indenie), 156
subspecies, most productive, 163
taste and quality in, 154
tetraploids, 143, 152
triploids, 150, 152
Ugandae x Robusta, 125
Hydrologic forests, 38

Imperata cylindrica, 23

Improved Casengo coffee, 116

Improved Liberica coffee, 109

Income from coffee per native family, 7

Increase in planting, 6

Indigofera endecaphylla, 26

I. erecta, 26

I. nata l, 86

Indonesia, in coffee history, 7

coffee industry in, 1, et seqq.

introduced coffee to, 5

introduction new species, 12

production increase and decline, 7

reductions in coffee, causes for, 7-8

stabilization of coffee growing, 8

Inga laurina, 78

Insects, 14, 17, 20, 24, 33, 41, 49-57, 78, 82, 85-88, 101, 110-114, 139, 145, 156-159, 165-168

on shade tree, 82

Interplanting (see Hevea)

Introduction of coffee to Arab world, 5

Introduction to Brazil, 100

Introduction to Java, 5

Introduction to Surinam, 5

Introduction to Tropical America, 5

Inyambane coffee, 136

Irrigation, 89

Ishiras coffee, 120

Italy early appreciation of coffee, 5

Ixora, 69

Jackson hybrid, 100, 102

Java (see Indonesia)

first coffee planted in, 5

Java Arabica, 142

Java Coffee, 3, 5, 8, 89, 142, 166, 171, 177, 178

hybrid origin, 158

introduction from Arabia, 7

Java hill land cycle, 8

Java history and coffee, 5

Kalimas coffee, 3, 146, 154
Kapakata, 14, 138-139, 143, 150-152, 161, 163
Katjang, 173
Katti (weight of coffee), 172
Kawisari Coffee, 3, 147, 150-153
Kents coffee, 102
Kenya coffee, 90, 138
Kopi daon (leaf coffee), 175
Kovilou, 174
Kried boon, 166-167

Lachnosterna severerini, 57

Lalang grass, 23, 83-84, 87

Lamborary coffee, 111

Lantoro (see Leucaena glauca), 23-26, 56, 78, 80-86, 173
 attack by Dompolan lice, 85
 budding to multiply, 86
 firewood, 86
 fruit fire hazard, 85
 green manure use, 84-85
 ground cover, 84
 seedless, 85-86
 seedless multiplied by cuttings, 85
 seedless multiplied by grafts, 85

Lantoro scale, countermeasures, 57

Lantoro shade, list of qualities, 84

Lantoro terracing, 84

Lanang coffee, 116

Lantana camara, 25

Laportea amplissima, 87

Lecanium viride, 41, 55

Leaf, composition studies, 21-23

Leaf, tea-like beverage from, 175

Leaf Disease (see Hemileia), 8, 41, 79, 122, 177
 cause of coffee failure, 8
 historical, 174

Leaves, abnormal, curled, 149

 stomatal numbers, chromosome counts correlated, 150-151
 stomatal openings, areas various, 150

Legkoffie (aged for quality), 165

Leguminous crop, auxiliary, 24

Leucaena (see Lantoro)

Leucaena glabrata, 85

L. glauca (see Lantoro)

 altitude, effecton, 84
 breeding, 86
 green manurer, 26
 hedge growing, 26
 hybrid sterile, 57
 mealybug, 56
 origin, 26
 planting seed, 26
 seedless varieties, 57, 85
 susceptible to Rhisectomia, 26
 windbreak, 26

L. pulverulenta, 56, 85

Liberia (country), seed from, 12

- Liberica (*Coffea liberica*)** 1-3, 6-9, 12, 19, 100, 105, 111-116, 125, 136, 139, 142, 144, 147-155, 162, 166, 169-170, 175, 177-178
adapted to low areas, 12
altitude effect of, 106
caffeine content, 169
clones, behavior of, 108-109
curing problems, 107
degeneration in, 92
description, 12, 105, 111
deterioration of selfed progeny, 108
distinctions from *C. excelsa*, 142, 150-151
early demand, 74
Hemileia rust in, 92, 106
history of, 12
importation to Ceylon, 44
Improved Liberica coffee, 109
improvement in, 108
leaf disease on, 92, 106
origin and name, 105-106
popularity and decline, 12, 106-107
prices secured higher than for Arabica, 166
production decline, 107
quality, 166
reaction to topping, 19
requirements of, 106
resistance, 78
selections, mother trees, 108
selections for soft berry, 108
selfed progeny, 108
species closely allied, 109
variability in, 107
varieties of, 110, 142
var. *indeniensis*, 110
var. *ivorensis*, 110
yields, 107-108
- Lice**, 56-57
- Linnean species**, 95, 116, 141
- Linnean**, 95
- Loss coffee**, 90
- Louis XIV**, his importance in coffee history, 5
- Lowwak Koffie**, 7, 52
- Lualaba coffee**, 136
-
- Macaranga tanarius**, 87
- Madagascar**, numerous coffee species in, 14
- Mallotus ricinoides**, 87
- Manihot**, 141
- Manihot glaucouii**, 87
- Manures (see Fertilizer)**
artificial, 21
Brazil system, 27
livestock, 145
organic, effects of, 22
- Markets, Amsterdam**, 166-167
color preferences in, 167
crisis, 166
- Market preparation, pounding**, 39
primitive, 39

- Maragogipe coffee, 102, 143, 153
Market product (see Beans)
 beans after dry treatment, 165
 beans, black, 168
 beans, borer damage, 167
 beans, color change in, 165
 beans, fermentation, 39
 beans, mixed with dedek, 165
 beans, musty moldy, 168
 beans, small, 166-167
 blending of coffees, 166-167
 color of beans in markets, 167
 curing with silverskin, 166
 destruction of (Brazil), 175-177
 differences in, 165-166
 dry cured, 167-168
 F. A. Q., 166
 fancy, 166
 first commercial lots, 5
 grade mixing, 165
 G. B., 167
 Indonesian, 177
 Java coffee, production data, 177-178
 Liberica compared with Arabica, 166
 moisture content standards, 168
 native, 167-168, 177
 native, borer damaged beans in, 168
 native, dry cure, 168
 native, legal restrictions on content, 168
 native, markets using, 168
 native, wet (W. I. B.) cure, 168
 stored, broken parchment mixed with, 165
 stored, enemies of, 165
 stored, moisture limits for, 165
 stored, paper seal to preserve, 165
 storod, problems in, 165
 telquel coffee, 166
 triage in standards, 168
 uses of different coffees in, 165-166
 wet and dry cured compared, 168
 world market for, 177
Marron coffee, 140
Martinique, place in history of coffee, 5
Mautsaka coffee, 169
Mealybug, 49, 56-57
 resistance in clones to, 57
 symbiotic with Polyporus, 49
 white, on Lamtoro, 57
Melia azedarach, 87
Menado coffee, 62, 97
Minor element deficiencies and excesses, 21-23
Mixochimaeras, 148
Mokka (also Moka and Mocha), 5, 65, 95, 99, 135, 162, 169
Mokka-like Robusta, 116, 121
Momordica charantia, 24
Monoclonal plantings, 60, 63, 163
 low yield in when Robusta, Excelsa, or Liberica, 60
 other clones at block corners, 163
Monopoly in coffee, by Government, 7
Mozambique, naturalized Arabica occurrence, 7

Mulch, 16, 23-27, 145
Multiplication in coffees, problems of, 59, 123
Munrovia coffee, 106

Nacional coffee (Brasil), 90
Nandi coffee, 14, 138
Native buying power increased, 7
Native coffees, 167-168
Native, cultivation of coffee, 135
 planters in Indonesia, 10
 plantings oldest, 8
 plantations, rental, 7
 preparation, 167-168
 production, and hill rice, 38
 production, government assistance, 38
 production, improvement of, 39-40
 production, in Bali, 38-39
 production, in Celebes, 39
 production, in Sumatra, 38
 production, of Arabica, 38, 178
 production, of Robusta, 38, 178
 production, primitive method, 38
 use, 113
 use, chowing dry berries, 175
 use, leaf drink from, 175

Nematodes, 18, 41, 50
 control by grafting, 50-51
 Excelsa and Robusta susceptible, 111
 in nurseries, 50
 pseudogalls and malformations similar to, 50
 resistance in Bgn.124.01 clone, 158
 resistance in clones, general, 51, 125, 158
 resistant hosts, 51
 susceptible hosts, 51
 soils cleared of by starving, 51, 73

Nephrolepis biserrata, 24

New Kinds of coffee produced, 9

New planting, shade, 27

New species of coffee, Indonesia introductions, 9, 12

Ngrangang ant, 56

Nitrogen supply in soil, 77

Nursery, clipping leaves in, 16-17

 cowperen system to reduce growth in, 17

 mulching in, 16

 planting of, 16

 selection in, 127

 shaded, 16

 transplanting from, 16

Oecophylla smaragdina, 56

Oeler Kawat, 58

Oerets, 57

O. I. B., or Oest-Indische Bereiding, 39

Oil, amount of in coffee, 176

Oil, essential from coffee flowers, 176

Opatrum, 58

Organic matter, effects of, 25

Ormocarpum senoides, 87

Ornamental shrub from coffee, 7
Orthotropic growth, 70
Osmoscope, 170
Other crops with coffee, 180
Overbearing, 68
 tolerance to, 103
Overproduction for commerce, its prevention, 7
Oxygen deficiency effect, 24

Palm oil, 10
Panicum ambiguum, 25
Paradoxurus hermaphroditus, 7, 33, 52
Parkia intermedia, 87
Parchment skin, 6, 39
Pasoemah coffee, 103
 crossed with Congusta, 160
 crossed with Robusta, 160
Paspalum conjugatum, 24
Passiflora foetida, 24, 25
Peaberry, 61-62
Pericarp, 6
Periploca, use in grafts, 14
Pests, 50
Physiological studies, 21-25
Phloem necrosis, in Surinam, 58
Phyllosticta spp., 48
Phytophomas, 58
Picul (weight), 165
Pink disease, 48
Piper nigrum, 141
Pisquin shade, 83
Plagiolepis longipes, 55
Plagiotropic growth, 70
Plastics from bean, 165-176
Planting altitudes for Congusta, 158
 areas of, 179-180
 avenue system, 19
 clonal, advantages in, 67
 effect of abandonment, 8
 government owned, 7-8
 government prohibitions in, 15
 private producers, 8
 years to abandonment, 8
Planting method, belt system, 19, 180
 distances, 18, 158-159
 effect from bent roots, 127
 for permanency, 40
 jungle belts, 27
 monoclonal, 67, 156
 native, 7-8, 16, 145, 179
 new land, 27
 nursery distances, 16, 68, 158-159
 nursery selection, 127
 old holes, 24
 old land, 77, 145
 replanting, 18, 77, 122
 resting of soil, 38
 seed bed, 16
 seed directly in field, 27

- self incompatibility consideration, 156
- tree branches used for, 39
- volunteer material used, 16, 38
- with other crops, 180
- Polyembryony, false, 62, 116**
- Polyspermy, 62, 116**
- Polyporus coffeae, 49**
- Portulaca oleracea, 24**
- Potash in bean, 172-173**
- Pollination (see Crosses, Breeding), 6**
 - Arabica in Brazil, 60
 - Arabica in Central Africa, 60
 - Arabica inside unopened bud, 59
 - Arabica self pollinated, 59
 - artificial, 60-61, 131-132, 163
 - by bees, 61
 - by wind, 60
 - controlled, 131-132
 - distant bee transfer of pollen not demonstrated, 61
 - emasculatation scissors used in, 62
 - for fertility crossings, 60
 - hand, 60-62, 153
 - insufficient, 61
 - interspecific, 61-62, 153
 - Liberica, 59, 108
 - monoclonal block and corner plantings, 132
 - monoclonal fields, 60
 - pollen grains defective, 60
 - pollen grains poor in interspecific hybrids, 60
 - pollen in wind, 60
 - pollen longevity in, 60
 - pollen mother cells, 147
 - pollen tube development, 59, 143
 - prevention of crossing with tents, 108
 - problems in, 143-144, 163
 - purposes of in breeding, 128
 - self incompatibility (Robustas etc.), 59-60, 156
 - testing occurrence in natural crossing, 60
 - with flit gun, 131
- Price correlations between Robusta W. I. B. and Santos Superior, 167**
- Price, government fixed, 7**
- Producers help from government, 168**
- Production (see Market Product, Yields), fertilization for, 21**
 - early history of, 7
 - grafting for, 18
 - index of, 124-125
 - long periods of, 38
 - selection for, 128-129
 - short periods of, 38
 - techniques of, 16-28
 - varieties compared, 100
- Propagation, cuttings for, 74-75**
 - generative, 59
 - grafting for, 63-74
 - vegetative, 63-75
- Proportions (see under Coffea species and coffee names), Abeokuta, 109**
 - Quillea, 119
 - Stenophylla, 135
- Proportion of yield in Hevea, 129**

- Prorops nasuta, 53
Pruning, agobiada method, 20
 branch grafts, 21
 candelabra, 20
 center pruning, 21
 Congusta, 159
 constructive, 21
 controls mealybug, 57
 formative, 21
 Kissing system, 20
 multiple stem, 19
 periodic, 21
 problems of, 19-21, 57, 93, 159
 purgative, 21
 rejuvenation system, 20-21, 93
 serial bud removal, 19
 stimulative for branch fans, 20-21
 stimulative for fruiting wood, 21
 stumping reaction, 20
 sucker removal, 19
 time of, 21
 two stem, 19
 undertree development in, 20
 wilde takken system, 19
 yield, reaction to, 19-21
Pruning of shade trees, 28, 57
Pseudococcus citri, 56-57, 166
P. deceptor, 49
Psilanthopsis, 139
Psychotria, 140
Puerto Rico and coffee introduction, 5
Pulpers, 33-35
- QP hybrids, 143, 150-152, 155-156
 climate for, 155-156
 resistance to berry borer, 156
 yields, 156
- Quality, 79, 113, 163-166, 168-170
 and altitude, 79
 body in, 165-166
 Coffee Fund standards, 168
 differences in species, 165, 169
 differences in trees, 170
 improved hybridizing with Arabica, 163
 in Robusta, 113
 often poor in low caffeine species, 169
 relation to fat content, 171
 subjective character, 170
 taste and flavor, 170
 unrelated, on analysis to caffeine content, 168-170
- Quillou (Coffea quillou) 13, 19, 20, 69, 116-120, 123-126, 144, 149-150, 162-163, 169-170, 178
 compared with C. robusta, 119
 description of, 119
 different from C. canephora var. kwiluensis, 13
 high productivity, 119
 history and origin of, 119
 selections from, 119, 125
 soil effect on, 119-120

- various names for, 120
- yield, 117, 119, 125

- Rainfall for coffee, 77-78, 113-114
- Rat of coffee, 7, 32, 33
- Rejuvenation, grafting Rogusta with Congusta, 159
 - periodic, 18
 - pruning for, 93
- Rental of plantations, 7
- Replacing poor yielders by grafting, 18
- Replanting, regular plan of, 18
 - reopened fields, 18
 - terracing in, 18
- Research, effects of, 8
 - history of, 8-11
 - planter, 8-9
- Research institutes, financed by industry, 11
 - for cocoa, 10
 - for coffee, 9-12
 - for tobacco, 10
 - general, 10
 - private, 10
 - publications from, 11
- Resistance, search against adverse conditions, 145
- Resistance, search against for diseases and pests, 145
- Reunion island, coffee introduction, 5
- Rhizoctonia spp., 26, 41, 48
- Rio coffee (Brazil), 166-167, 171
- Ripening differences in species, clones, varieties, 32
- Ripening periods required, 32
- Roasting (see Bean), change in volume, 167
 - dull appearance, 172
 - equipment for, 171
 - experiments on, 172
 - loss in weight from, 167
- Robusta (Coffea robusta selected from C. canephora), 1, 12, 17-21, 24, 103, 113, 119-126, 128-130, 133-139, 143-144, 147, 149-159, 162-163, 166, 168-171, 175, 177-179
 - altitudes for planting, 114, 125-126
 - aroma of, 113-114
 - beans of, 126, 128, 159, 167, 170
 - bean selection for size, 170
 - bean size and weight, 126, 159, 167, 170
 - Bgn.124.01 special grafting clone, 158
 - characteristics, 12, 113, 128
 - chromosome numbers, 116
 - climate for, 103, 113
 - clones, 10, 108, 122-125, 129, 133, 158, 170
 - clone variation, 123
 - compared with other species, 113
 - conditions for growth, 113
 - countries of production, 113
 - crosses with Kapakata, 143
 - degeneration problem in, 92, 122-124
 - early reports on, 114
 - estate selection, 122
 - false polyembryony, 116
 - favorable in Dutch East Indies, 113
 - flavor, selections for, 108, 170
 - flavor variability in clones, 108

from *C. canephora*, 150
harvest time for, 137
hereditary varieties, 116
highest producers among hybrid types, 163
history of, 2, 12, 13, 113, 154
hybrid nature of, 151
hybrids (see also under Breeding and Crossing), 149
improvement in, 122
introduction to Java, 12, 113
kinds of (Robustoids), 119
little star flowers, hereditary nature, 117
male, 116
market acceptance, 113
monoclonal fields of, 124
mother trees, 124
mutations in, 116
native production of, 167-168, 178
nematode resistance in clone, 125
origin, 12-13, 113, 154
origin, erroneous statement on, 2
original conditions of growth, 113
planting distances, Java, 18
planting, new, 13
polyspermy in, 116
preference over Liberica, 114
productivity, early history, 13, 178
productivity, more than Arabica, 93
pruning by bending, 20
pruning in, 19-20
pruning, topped low, 19
quality in, 165
R.124 clone, 124-125
replacing old Arabica with Robusta, 13
Rust on, 114
Rust resistance in, 8
root system of, 127
seedling families, 125-126
selections, bean size, 170
selections, tree basis, 124-126, 129
self incompatibility in, 143
soil relations, 114
species allied, 116
study of, 9
susceptibility to green scale, 114
variability in, 116, 125
variability compared with others, 116
variability of clones, 123
variability of flavor in clones, 113
varieties, var. Angola, 116
var. Bajos Lor Grootboom, 126
var. Bullata (type) 97, 116, 149, 150
var. Djamboe, 149
var. Improved Casengo, 116
var. Ivory Coast, 121
var. Lanang, 116
var. Large Berry type, 126
var. Little Cabbages, 116
var. Moemboel, 126
var. Mekka-like, 116, 121
var. narrow leaved, 143

- var. pendula, 116
- var. Petit Indenie, 120
- var. purpurascens, 98, 116
- var. Quillou, 120
- var. Ugandae, 120-121
- var. red leaved, 116
- var. Sierra Leone (mixed Java and Congo types), 169
- var. Spontan, 121
- var. Touba, 121
- var. yellow fruited, 116
- wild occurrence, 12
- yields, 38, 111, 114, 117-118, 123, 126, 129
- yield and age, 123
- yields compared with Excelsa, 111
- yields correlated with rainfall, 38, 114
- yields, early tests in, 114
- yields, effected by uncontrollable factors, 126
- yields, highest in young trees, 38
- yields of trees interplanted with rubber, 115
- yields, proportion, 129
- yields, proven clones compared with unimproved, 123-124
- yields, selection for, 124
- Rooting cases for cuttings, 75
- Roots, bents in planting, 127
 - bents from soil conditions, 127
 - competition in for oxygen, 24
 - crooked in natural field plants, 16
 - cutting produced, 74-75
 - development, 74
 - diseases of, 49
 - grafting of, 64-66
 - in peaty soil, 77
 - pruning at transplanting, 18
 - pruning in stumped trees, 20
 - rot resistance in Columnaris, 99
 - toxic injury to, 26
 - toxins in, 25
- Root systems, compatible with coffee and lantoro, 85
 - Congensis, 137, 142
 - Excelsa, 111
 - Robusta, 127
 - Robusta effected by grafting, 69
 - shade tree, 81
 - shade tree compared with coffee, 85
- Rosellinia bunodes, 49
- Round beans, 61-62
- Rubber, 10, 23, 26, 38-39, 115, 124-125, 179-180
 - coffee grown between, 38, 115
 - interplanting catch crop of coffee, 38, 115
 - production index in, 124-125
 - rehabilitation with, of old coffee, 179
 - pushed out coffee, 38
 - Robusta combined with, 38-39, 180
- Rubiaceae, 140
- Rust (see Hemileia, Disease)

- Salvia, cover crop, 25
 - erect and prostrate, 25
 - noxious to coffee, 24-25

- Salvia obscura, 24
- S. occidentalis, 24-25
- S. privoidea, 24-25
- Santos coffee (Brazil), 166-167
- Scale (insect), 41
 - ants attending, 55
 - attack effects quality, 166
 - serious on Congustas, 158
- Scarabaeidae, 57
- Scion wood most suitable, 70
- Scymnus on lice, 56
- Seed, abnormal rejection in planting, 16
 - commercial production, 9, 131-132
 - cotyledons in, 16
 - embryonal cavity in, 16
 - for planting, 9, 16, 131-132
 - germination course of, 16
 - hypocotyl, 16
 - improved, 131-132
 - legitimate, 132
 - natural spread by coffee rat, 7
 - produced in station, 9
 - production fields, biclonal, 163
 - production fields, monoclonal, 163
 - selection for sale, 124
 - selection, mother tree, 124
 - size and weight for planting, 16
 - storage, Arabica and Robusta, 17
 - storage, conditions for, 17
 - storage, in charcoal, 17
 - storage, moisture percentage, 17
 - storage, problem of, 17
 - storage, treatment for Berry Borer, 17
 - storage, variation in clones to withstand, 17
 - ripening of with ethylene gas, 17
 - yellow color in, 6
- Seed beds, 16
- seedlings, 16-17
 - clipping leaves of to slow down growth, 17
 - families selected, 130-132
 - production compared with clones, 67-68
 - stage kepelans, 16
 - stage little soldiers, 16
 - stage soldaatjes, 16
 - strains, 163
- Selecting of an estate, 126
- Selection, advantageous results in Robusta, 123-124
 - chromosome counts in, 150
 - coefficient of superiority, 125, 132
 - early seedling stage, 127
 - effect on bean size, 128
 - for superiority, 125
 - grafts, 132-134
 - high yielders, offspring unpredictable, 129
 - ideal tree, 129
 - in the nursery, 127
 - mother tree expression in grafts, 132
 - mother tree for vegetative multiplication, 129
 - mother tree seed producers, 129
 - of Robusta, 124, 128-134

production index in, 124-125
top class, 129
yields of Robusta seedlings, 130-132
Sengon, 27

Sengon looet, 82

Sesbania egyptiaca, 87

Shade, 8, 9, 16, 20, 23, 25, 27-28, 38-39, 56-57, 80-89, 100, 115, 145

advantages from, 81

Arabica naturally shaded, 89

Arabica, need for, 115

auxiliary, 87

complications from, 80-81

fertiliser value, 81

fields newly opened, 27

fields rejuvenated, 20

frost protection by, 81

fungicidal sprays on shade trees, 83

growing coffee without, special conditions, 80

humus production by, 82

inadequate, reduces humus, 145

in countries, Abyssinia, 80

in countries, Africa, 80

in countries, Bali, 80

in countries, Belgian Congo, 80

in countries, Brazil, 80

in countries, Celebes, 39

in countries, Central America, 80

in countries, Ceylon, 80

in countries, Colombia, 80

in countries, German East Africa, 80

in countries, Guatemala, 80

in countries, Hawaii (Kona), 80

in countries, India (South), 80

in countries, Madagascar, 80

in countries, Sumatra, 80

in jungle over wild coffee growth (see also origin of coffees), 80, 89

for moisture conservation, 81

for native plantings, 8, 38-39, 80

for Robusta, 115

for soil amendment, 23, 27, 82, 145

increase and reduced coffee yield from, 100

mealybugs effect by, 56-57

nursery use of, 16

problem of, 87

protection by Government for water supply, 38

pruning necessary, 88

regulation, 88

regulation for pest control, 57, 88

study of, 9

suitable and unsuitable types, 87

temperature regulation by, 81

three series of, 57, 88

wild coffee requirement, 80, 89

Shade trees, 27, 86, 145

breeding of, 86

caterpillar on, 87

cuttings of seedless lamtoro, 85

firewood from, 86

forest nature of, 38

grafting of, 85

- insects on, 56-57, 82, 87-88
- miscellaneous, 86-87
- mixture of, 88
- pruning of, 28, 88
- Shedding of fruit, 30, 160
- Silver skin of bean, 6, 61, 166
- Skins (of berry or cherry), 33
 - briquettes from, 33
 - compost from, 33
 - demand for, 175
 - exportation of, 175
 - for fuel, 33
 - for substitutes of bean, 172, 175
 - Liberica preferred, 175
 - separation from bean, 35
 - use of, 175
- Soap emulsion, 56-57
- Soils, 8-9, 23-27, 77, 83-84, 103, 111, 117-118, 145
 - carpet formers, effect on, 24
 - cause of bent roots, 127
 - clays, 77, 111
 - cover with auxiliary crop, 24
 - digging of, 23-24
 - drainage in, 77
 - erosion prevention in, 27
 - Excelsa grown in clays, 111
 - humus cover on, 24, 27, 77, 145
 - humus from shade trees on, 82
 - humus in, 27, 77, 145
 - humus preservation in, 27, 77
 - humus protected by jungle belts, 27
 - humus, waste of, 27
 - ideal for coffee, 8, 27, 77, 145
 - improved by shade, 83
 - improvement study (see Fertilizers), 9, 83
 - jungle, 8, 27, 145
 - lateritic, 77
 - lime in, 77
 - maintenance for coffee, 23
 - newer volcanic, 77
 - nitrate removal by root competition, 24
 - nitrogen increased by lamtoro, 84
 - noxious excretions in, 24
 - old forest, 27
 - old plantings in, 8
 - older cared for, 77
 - peaty, 77
 - platforms, 27
 - protection by shade, 27
 - Robusta growths in, 114, 117-118
 - root competition problem, 24
 - topsoil preservation, 27
 - terracing, 27
 - virgin, 145
- South America increased planting, 6
- Species (see different coffee names, under hybrids, breeding, crosses, etc.)
 - Asiatic, 142
 - caffeine free, 169
 - concept in coffees, 141
 - good, 141-143

- groups of, 141-143
- groups within, 162
- hybridisation within, 162
- lesser, 178
- Linnean, 116, 141
- Linnean, the, 95
- mutation and variation within, 141
- numbers of in Coffea, 7, 141
- progress dependent on new species, 8
- subspecies, 162
- Spontan coffee, 121
- Stenophylla (Coffea stenophylla) 13, 91, 97, 104, 113, 135-136, 142, 144, 148, 152-153, 156-157, 169
 - beans of, 135
 - description of tree, 135-136
 - distribution, 135
 - flavor superiority in, 135
 - hybrids with, 157
 - origin, 13, 135
 - parchment and silver skin, 135
 - region of wild occurrence, 135
 - resistance to Hemileia, 135-136
- Stephanoderes (S. hampei, also see Berry Borer), 26, 41, 51-54, 101, 156, 158, 166-167
 - altitude effects, 53, 158
 - and green manurers, 26
 - appearance in Indonesia, 41
 - bean damage from, 166-167
 - enemies of, 53
 - life history of, 52
 - resistance to, 101, 156
 - susceptibility to, 53-54, 158
- Stephanoderes subopacus, 54
- Sterretjes bleel (see Star flower and Virescence) 32
- stink coffee, 166
- Storage (see Bean and Market Product), aged coffee preferred, 165
 - loss of flavor in roasted bean from storage, 172
 - weevil in, 165
- Stumping, conversion by grafting after, 20
 - reaction to, 20
 - to rejuvenate, 72-73
- Subspecies, 162
- Substitutes (see Adulterants), 172, 174-176
 - caffeine extracted beans, 174
 - plant parts other than bean, 174-176
- Sultana coffee, 175
- Sumatra and coffee growing, 8
- Sun, on coffee, sudden exposure to injurious, 57
- Sun, on coffee, under exceptional conditions grows, 80
- Sun, tropical, effects on coffee soils, 145
- Superior trees, search for, 132
- Superiority, coefficient of, 125
- Surinam coffee, 79
- Surinam, history of coffee in, 5
- Symbiosis, insect and fungus, 49

- Taste (see Quality, Bean, Market Product), 167, 170, 173
- Taste, musty, 165
- Tax, for help to coffee producers, 168
- Tea, 26, 129, 174

- Tea, yield proportion in, 129
- Tea-like beverage from coffee leaves, 175
- Technical efficiency, studies in, 9
- Telquel, 37, 167
- Tephrosia, 78
- T. candida, 26
- T. vogelii, 26
- Tijil weed control, 23
- Tissue analysis (see Fertilizers, Leaf Composition)
- Top dieback, 41
- Top disease, 48-49
- Top grafts, 69
- Topping, Bangelan method, 19
- Topping, different heights of, 19
- Topping, gradual method of, 19
- Topping, Semeroe method, 19
- Touba coffee, 121
- Transplanting, bareroot (tjaboetans) method, 17-18
 - earth left on roots (poeterans) method, 17
 - nursery selection for, 17
 - old stumps (overjarige) method, 17-18
 - time for, from nursery, 16
- Trema sp., 87
- Triage, 168
- Trianthema portulacastrum, 24
- Triticum compactum, 116
- T. spelta, 116
- T. vulgare, 116
- Trypanosomide, 58
- Tubruk, native coffee brew, 168
- Tylenchus acutocaudatus, 50
- T. coffeae, 50
- T. similis, 50
- Typhlocybe erythrinae, 82

- Uganda coffee, 156
- Ugandae (Coffea canephora var. ugandae), 13, 14, 23, 116-117, 120-126, 144, 148, 150-157,
 - 162-163, 170, 178
 - clones special for seedlings, 163
 - hybrid nature of, 163
 - hybrids, 121, 163
 - origin, 13
- Upkeep, 23

- Variability extreme in hybrids, 153
- Variation, homologous, 149
- Varietal hybrids, 162-164
- Vavilov, law of homologous series, 95, 116
 - plant collection of variants, 144-146
 - principles of introductions, 9
 - theory, origins of diverse types, 139
- Vigna sinensis, 24
- Virescence, 32, 107, 110
 - clone with, 107
 - flowers turned to leaves, 32
 - heredity of, 107
- Voosboon, 61

Weather, bad, factor in Robusta, 122
dry season occurrence favorable for coffee, 78
factors in coffee, 8, 77-78, 122
factors, local shower studies, 78
importance as a factor for Arabica, 8

Weeding, clean method, 24
Djombret method, 24
selective system, 24
time of, 28
types of compared, 24

Weeds, grass as, 84
harmless, 24
noxious, 24
remedy for, 23

Western Europe use of coffee, 5

West Indian curing (see Wet Process, W. I. B.), 33

West Indies, coffee introduced to, 5

Wet Process of curing, 33-34, 37, 167-168, 170

Weevil of stored coffee, 165

White grub, 57

Whip branches, 70

W. I. B., Wet or West Indian method, see Wet Process

Wild coffee, occurrence and growing conditions, 12, 14, 80, 135, 138, 143-145

Wild forms of coffee, search for, 144-145

Wild species, study incomplete, 14, 143

Wild types, variability greater in, 144

Wilt disease, see Phloem Necrosis

Wind, damage to shade trees, 80

Wind, protection from 77-78, 80

Windbreaks, 78

Witboon, 34

World Markets, 166, 177

Xylaria, 49

Xyleborus morstatti, 54

Xylosandrus morigerus, 41, 54-55

X. morstattus, 54

Xylotrechus javanicus, 58

X. quadrupes, 58, 110

Xylotrechus sp., 103

Yields, age and, 123
grafts and mother tree comparisons, 129-130
grafts, whip branch, 71
harvest, 137
heredity in Robusta, 132
increase expectations from selections, 128-129
native plantings, 179
problems of, 132
pruning effect on, 19-20
related to chromosome number, 152
seedling families and, 130-132
selection for, 128-129
special clones for, 130-133

Yield values classification, 129

Yield variations, annual, 129

Yielders, poor, replacement of, 18

Yield produced in coffees, Abeokuta, 109
Arabica, 91-92, 101, 116
Congensis, 137
Congusta, 158
Excelsa, 111
Liberica, 107-108
QP hybrids, 156
Quillou, 117, 119, 125
Robusta, 38, 111, 114, 117-118, 123, 126-132, 177-178
Ugandae, 125



FECHA DE DEVOLUCION

| | | | |
|--|--|--|--|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

