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ABC OF VEGETABLE FARMING
A DRAFT HIGH SCHOOL TEXTBOOK

VOLUME I

THE A,B,C OF VEGETABLE FARMING

By: Neville Farquharson
(B. Sc. Dip. in Agric.)

PART I.

DRAFT OF ORIGINAL

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"AGRICULTURE IN JAMAICA"

Collection of papers of the Office of IICA in Jamaica.

1977 - 1978

No. I - 1. Fritz Andrew Sibbles, "Basic Agricultural Information on Jamaica", Internal Document of Work, January, 1977.

No. I - 2. Yvonne Lake, "Agricultural Planning in Jamaica", June, 1977.

No. I - 3. Aston S. Wood, Ph.D. "Agricultural Education in Jamaica", September - October, 1977.

No. I - 4. Uli Locher, "The Marketing of Agricultural Produce in Jamaica", November, 1977.

No. I - 5. G. Barker, A. Wahab, L.A. Bell, "Agricultural Research in Jamaica" November, 1977.

No. I - 6. Irving Johnson, Marie Strachan , Joseph Johnson, "Land Settlement in Jamaica", December, 1977.

No. I - 7. Government of Jamaica, "Agricultural Government Policy Papers", February, 1978.

No. I - 8. Jose Emilio Araujo, "The Communal Enterprise", February, 1978.

No. I - 9. IICA and MoAJ "Hillside Farming Technology - Intensive Short Course", Vols. I and II, March, 1978.

No. I - 10. Jose Emilio Araujo, "The Theory Behind the Community Enterprise-Seminar in Jamaica", March, 1978.

No. I - 11. Marie Strachan, "A National Programme for the Development of Hillside Farming in Jamaica", April, 1978.

No. I - 12. D.D. Henry, "Brief Overall Diagnosis of Hillside Farming in Jamaica", May, 1978.

No. I - 13. Neville Farquharson, "Production and Marketing of Yams in Allsides and Christiana", May, 1978.

No. I - 14. R.C. Harrison, E.McDonald, A.H. Wahab, "Fertility Assessment of Newly Terraced Hillside Soils using the Microplot Technique, the Allsides Case Study", May, 1978.

No. I - 15. IICA - IDB "Course in Preparation and Evaluation of Agricultural Projects", Vols. I and II, November, 1977.

No. I - 16. Neville Farquharson, "Production and Marketing of Dasheen in Allsides and Christiana", June, 1978.

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II - 1 O. Arboldea-Sepulveda (IICA-CIDIA),"Agricultural Documentation and Information Network in Jamaica (Elements for a Proposal)

II - 2 Victor Quiroga,"National Agricultural Information System (NAIS - Jamaica) Project Profile, September, 1978.

II - 3. Joseph S. Johnson "A Review on Land Reform in Jamaica for the Period 1972-1978" September 1978.

II - 4. Neville Farquharson, "ABC of Vegetable Farming" A Draft High School Textbook. Volumes I, II, III and IV February 1979.

FOREWORD

IICA - Jamaica - who recognised the need - with financial assistance from the Canadian High Commission and the Royal Netherlands Embassy, spearheaded the preparation of "ABC of Vegetable Farming" - a high school textbook to teach Agriculture.

"ABC of Vegetable Farming" is a revolutionary step in Caribbean secondary education, in that it seeks to provide that much talked about agricultural textbook information which was hitherto conspicously absent.

This most important break-through and the information provided therein are in line with the philosophy of Caribbean Governments and the Jamaican Ministry of Agriculture which clearly indicates that children at primary and secondary stages of education should be exposed to agricultural education.

While no praise can be too high for IICA, the Canadian High Commission, the Royal Netherlands Embassy and Jamaica (Ministry of Agriculture) for their sterling contribution, special tribute should be paid to two members of the staff of the Ministry of Agriculture, Jamaica:- Mr. Neville Farquharson who prepared the original document in 4 volumes and Garnet Malcolm who read and assisted in editing the document.

It is my wish that "ABC of Vegetable Farming" will not only find pride of place in school and home libraries, but will be used to the extent it will assist in guiding teachers to impart, and students to become eminent fellows in their fields of endeavour. For the youth to whom this textbook is dedicated, I am sure it will become a guiding influence.

Derrick Stone
Permanent Secretary
Ministry of Agriculture of Jamaica.

PROLOGUE

The office of IICA/Jamaica is extremely pleased that the proposed book titled "ABC of Vegetable Farming" has reached this draft stage of preparation.

The fact that this activity became possible once IICA had thought of the idea was due in large measure to the financial assistance provided by the Canadian High Commission and the Royal Netherlands Embassy, to both of whom we are profoundly grateful.

There is little doubt that the proposed text-book will fill an important gap in the education of the youth of the English speaking Caribbean countries. The existing high dependence on agriculture; the low status of agriculture in most of these countries and the associated low incomes of rural dwellers, most of whom rely on agriculture for a living; the high degree of rural/urban migration and the social costs associated therewith, are factors which make it necessary to take early steps to inculcate into our youth knowledge concerning agriculture. This book is a contribution to that effort.

While expressing my pleasure with the outcome of this venture and the catalytic role which IICA/Jamaica has been able to play. I also record my fervent hope that this book will be only the first in a series of such publications.

In the above context I must also express our pride in having been able to work with Mr. Neville Farquharson of the Ministry of Agriculture, Jamaica on this activity.

This draft preparation is being presented to a number of key personnel in the English speaking member countries of the Caribbean for suggestions for modification where appropriate. These suggestions will then be made available to IICA's Central Office in San Jose for the attention of Carlos Molestina, Director of Public Information and Publication. The book in final form is expected to be the result of action to be taken by IICA's Headquarters at San Jose.

Percy Aitken-Soux PhD.
Director, IICA Office, Jamaica.

TABLE

OF

CONTENTS

ACKNOWLEDGEMENTS

The "A,B,C of Vegetable Farming", took me many tears to prepare, working on it mainly during vacations from my studies and from my regular work at the Ministry of Agriculture (Jamaica). During this time, the number of people who have provided information, helped to arrange visits to farms, provided a place for me to stay in different parts of Jamaica or helped in some other way, the names are too many to mention here. But I would be more than ungrateful if I did not mention the individuals and agencies without whose help this publication would not have been possible; Dr. John Hammerton of the Faculty of Agriculture, University of the West Indies and Garnet Malcolm, Agronomist, who both read the manuscript and offered valuable suggestions to improve the work; Mr. J. Donaldson and Conan Barrett, both vegetable specialists formerly working at the Ministry of Agriculture and the other people working in this Ministry, especially in Extension, Crops and soils. The Agricultural Planning Unit and Ms. Marjorie Grant of the Data Bank the Agricultural Education Department of the Ministry of Education especially Patrick Bennett, R. Grey and J. McKenzie.

My deepest thanks to my family and close friends who have helped in every way with this book. I must single out Jannette Farquharson, Junior Rimple Marsh, Glen Ferguson, Joselyn Williams and Lindel Farquharson for special mention. Also thanks to the many farmers throughout Jamaica who spent their valuable time providing information for this work.

My recognition and thanks to Dr. Percy Aitken - Soux, Dr. A. Wahab, and Ms. Josephine Kerr of the IICA OFFICE IN JAMAICA and Mr. Harry Forbes of the Canadian High Commission and Mr. Maurits Jochems of the Royal Netherlands Embassy for their encouraging support and financing for the publication of this book.

Neville Farquharson
September, 1979.

INTRODUCTION

THE A,B,C OF VEGETABLE FARMING

In my years of studying and working in agriculture, I have found a serious lack of books on agriculture in the Caribbean countries. Generally this is a problem affecting farmers, students and teachers.

At Primary School in the early 1960's, we had no books on agriculture for students. At College, in the late 60's there were many books, but only a few written in the Caribbean for the conditions in these countries.

In the early 70's after leaving college (J.S.A.) to teach agriculture, again, there were hardly any books to use. It is this great lack of text books on agriculture suitable for Caribbean students which inspired me to take up the task of writing a book on a major area of agriculture, namely, vegetable farming.

This book is on vegetable farming for students especially in the Junior Secondary, Technical, High Schools and even the first year in College. It is based mainly on studies and field work which I started in 1970 when I began teaching Agriculture at the May Pen Junior Secondary School in Jamaica. Later I continued this work at the McGrath Junior Secondary School up to 1973.

While at the University (of the West Indies) and working at the Ministry of Agriculture (1974-1976), I spent a great deal of time travelling into the farming areas of Jamaica, talking to farmers, observing how they grow their crops. I have had to spend some time visiting school farms, talking with teachers and students in addition to dealing with crop specialists in the Ministry of Agriculture and the University.

The first point I am stressing is the importance of basing a text-book on conditions which are similar to those that the student will have to grow up and work with. This is not saying that information on vegetable farming as it is practised in temperate countries is not important. It is , but the book for tropical agriculture must be based on climatic and other natural conditions, and the pattern of agriculture in these countries. Then information from temperate sources can be used if it can be applied to tropical conditions

in a way that will help to improve farming for the majority of farmers in the country.

To give an example, one could spend a lot of time writing about growing vegetables in a green-house when the majority of students in the Caribbean have never seen a green-house in their lives.

Apart from the need to write this book relevant to the conditions in the Caribbean, I have tried step by step to write about the theory and practices in vegetable production. Most important, this book tries to encourage the experimental approach in teaching and learning vegetable farming. More and more it is necessary to do experiments with different crops to determine which one and how best it can grow to give good yields. The School Farm in a community, if it is properly organized and operated, can be a centre of learning for both students teachers and farmers. The A,B,C. of Vegetable Farming is intended to provide students with the basic theory and practical knowledge which can be used as a guide to vegetable growing on a school farm which can be centre of agricultural learning in the community.

In Part I we deal mainly with some basic theory about the vegetable plant and soil. Botany and Soil Science provides a sound foundation for a student of vegetable farming. It is very important to understand how the plant is made up; how it functions; how the soil is made up; how and why it helps to keep the plant alive. With this knowledge, a vegetable grower, is better able to see the need for example to use the correct fertilizers for the crops grown on his farm.

While most farmers in the Caribbean, even successful ones do not have the basic knowledge about the plant and the soil, had they got this knowledge they might have made fewer mistakes and be more successful.

Students must have these 'groundings' to become successful agriculturalists.

The later 3 parts will deal with the more practical side of vegetable farming viz:

- Cultivation practices in vegetable growing.
- How to grow different vegetable crops.
- How to set up demonstration and experiments on the school farm.

I hope that this book will help to turn out a new generation of agriculturalists and farmers more successful than my generation.

A,3,C, OF VEGE1ABLE FARMING
PAR. I - BOTANY & SCIL SCIENCE)

CONTENTS **PAGE**

SECTION I - BOTANY OF THE VEGETABLE PLANT

SECTION II. SOIL SCIENCE

INTRODUCTIING VEGETABLES

CHAPTER I VEGETABLES PRODUCTION AND AGRICULTURE

Agriculture is the practices of cultivating the land mainly for food. It involves the raising of plants and animals on the land. Although most of what is produced is used as food, some are used for many other purposes. For example, raising horses and growing tobacco are all part of agriculture. Man has been engaged in agriculture from the first day he planted a seed or put a wild animal in a pen. This started hundreds of years ago and today, millions of people are engaged in agriculture. The majority of these are farmers. They do agriculture as a business and make their living from it. The farmers and the agricultural workers feed us all. Agriculture is the source of food for all mankind.

What is a Vegetable?

The question of what is a vegetable .is one of that cannot be easily answered. A commonly given definition is that a vegetable is a crop used to make vegetable salad. The real situation is that few people seem to be very concerned about a very precise definition.

For instance, one of the most widely used dictionaries defines a vegetable as follows - plant especially one of the kind normally prepared as food by cooking. Now by this definition, cabbage is a vegetable and so is the banana fruit. But not many people will be easily convinced that banana is a vegetable. What is more important than a definition of vegetables is for us to know the crops that we will be studying.

Types of Vegetable Crops.

Vegetable crops can be classified into 3 main groups according to the plant part that is most commonly eaten. These are:-

Fruit and Seed Vegetables - i.e. Vegetables mostly grown for its fruits and seeds. eg. corn, tomato beans

Leaf and Stem Vegetables - i.e. Vegetables mostly grown for its leaves and stem eg. cabbage, lettuce.

Root and Tuber Vegetables - i.e.Vegetables mostly grown for its tubers. These may be stem or root tubers eg. potato, turnip.

Note - 1. Although a vegetable is grown mainly for one plant part, another part might also be eaten eg. turnip is grown mainly for its root tubers, but its leaves can also be eaten.

2. There are some crops that do not easily fall in the 3 above categories. This is mainly because the part or parts that are eaten, does not fit into the main groups. Such, crops can be grouped as - Miscellaneous vegetables.

(1: 1) Here is a list of some commonly grown vegetables in the different groupings:-

Fruit and Seed Vegetables.

Beans	Muskmellon	Pumpkin
Corn	Okra	Squash
Cucumber	Peas	Tomato
Cauliflower	Pepper	Water-mellon
Egg-plant (garden-egg)		

Leaf and Stem Vegetables.

Amaranth (calalu)	Celery	Lettuce
Brocolli	Chard	Mustard
Brussels sprout	Collard	Parsley
Cabbage	Endive	Rhubarb
	Kale	Spinach

Cont'd...

Root and Tuber Vegetables.

Beet	Kohi-rabi	Potato
Carrot	Onion	Radish
Garlic	Parsnip	Turnip

The fruit and seed vegetables are usually called the fruit vegetables, the leaf and stem vegetables are called the leafy vegetables, and the root and tubers are the root vegetables.

Vegetables can also be grouped according to their families.

THE VEGETABLE PLANT IN FAMILIES - (Classification.)

Most vegetables fall in the group of plants called Angiosperms. These are all Seed plants. Two sub-divisions of this Angrosperms are:-

Monocotyledons - plants producing seeds with a single cotyledon e.g corn.

Dicotyledons - plants producing seeds with two cotyledons. eg. Kidney beans.

The plants in each sub-division are grouped into a number of families.
(1: 2) Some monocotyledonous families and the common vegetables in these families are:-

1. Corn family. (Gramineae.)
   Corn

2. Leek Family. (Liliaceae.)
   Leek Onion.

Some dicotyledonous families and the common vegetables in these families are:-

1. Beet family (Chenopodiaceae)
   Beet Swiss chard Spinach.

2. Cabbage family. (Cruciferae)

Brocolli	Brussels sprout	Cabbage
Cauliflower	Chinese cabbage	Collard
Kale	Kohl-rabi	Mustard
Radish	Rutabaga	Turnip.

Cont'd...

3. <u>Cucumber family</u> (Cucurbitaceae)

Cucumber	Muskmellow	Pumpkin
Squash	Watermellon	

4. <u>Lettuce family</u>. (Compositae)

Artkichoke / Lettuce

5. <u>Okra family</u>. (Malvaceae)

Okra.

6. <u>Parsley family</u> (Umbelliferae)

Carrot	Celery	Parsley
Parsnip	Turnip	

7. <u>Pea family</u> (Leguminosae)

Beans	Peas	Peanut
Lima beans	Cow pea	
Kidney beans	Garden pea	
(red peas)	(green pea)	
Snap beans		
(string beans)		
Soyabeans		

8. <u>Tomato family</u> (Solanaceae)

Egg plant	Potato	Pepper
Tomato		

(See Appendix I for Botanical names of crops.)

<u>Importance of Classification</u>

Classifying the vegetables according to their families is important. Plants within the same family have many features in common. For example, members of the same family usually have leaves resembling each other and their growth habits - (i.e. the way they grow) are often similar. The same insects that attack one member, usually attack all other vegetables in the family.

Similar features often makes it necessary to use similar treatments in growing members of the same family.

What are Varieties?

There are different types of each vegetable crop. These are called varieties. Each variety usually has a feature or a number of features which distinguish it from the other varieties. They may be differ in -

(1) Shape - eg. Drum-head variety of cabbage is oval while Early Jersey is conical.

(2) Size of plant or part of plant eg. Charleston Gray watermellon usually produce bigger fruits than the Sugar Baby variety.

(3) Colour of whole plant or part of the plant-eg Red Dutch is a purple coloured cabbage while Flat Dutch is green.

(4) Taste - eg. Bravo is a sweet variety of corn while Pioneer X 304 is not.

(5) Other features like ability to resist a certain disease, capacity to produce and growth habit-eg. Contender is a variety of bean with plant growing relatively short, while Kentucky Stringless is a plant which grows for several feet.

How are they named?

Varieties are usually named from-

(1) The places in which they were developed, eg. Great Lakes lettuce is named after the Great Lakes in North America.

(2) Certain features of the plant or part of the plant-eg. Long Green cucumber.

(3) An individual or groups of individuals that developed the variety eg. Pioneer Hybrid X 304.

Sometimes other features may be used

Chapter 2 THE VEGETABLE PLANT AND ITS PARTS

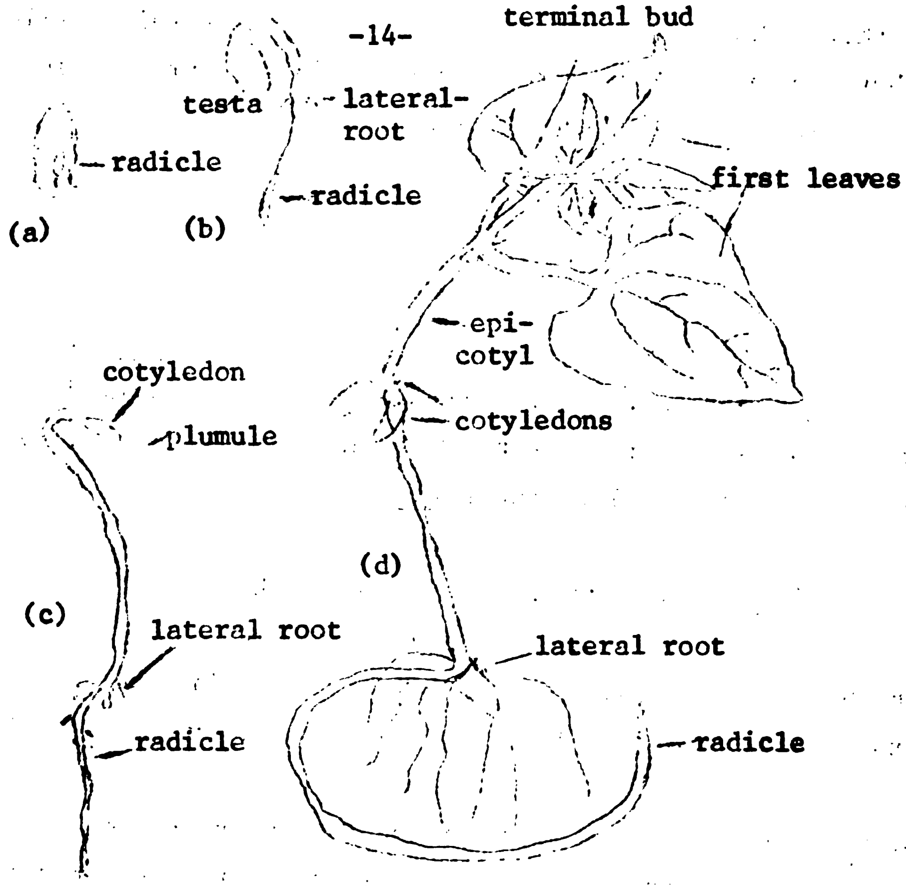
The structure or make - up of the vegetable varies from one crop to another. Some plants have leaves and stems of different shapes, flowers of different shapes and colours and roots of various lengths among other things. It is these different features that makes it possible to distinguish one crop from the other. But most vegetables are seeds plants (also called flowering plants), and have certain basic forms similar to all plants within this category. It is these features that we will look at in this section.

A. STRUCTURE

The seed plant consists of two main parts. (1) The shoot - the portion usually above the ground. It is made up of a stem bearing leaves, buds and flowers. A few , for example the potato, has part of the shoot below the ground. The shoot is sometimes called the foliage.

(2) The root - the portion usually below the ground. It consists of a main root in dicots with a number of secondary roots branching from the main root. On both primary and secondary roots are fine thread like structures called roots hairs. This is called a tap - root system eg. in Kidney bean.

Most monocots do not have primary and secondary roots. They secondary roots growing directly from the stem. Root hairs are also present. This is called a fibrous root systm. eg. corn.



(2: 1) <u>SEED PLANT - KIDNEY BEAN</u>

The above drawing of the plant shows the main features of Seed plants.

<u>What are Cells?</u>

Cells are the small units that make up the parts of all living organisms - namely plants and animals. Each plant cell, is made up of a small amount of non-living material(ergastic substances). However the bulk of the young cell material is a living substance called <u>protoplasm</u>. The nucleus controls the functions that take place within the cell. It controls food manufacture and production of energy in the cell and also play an important part in growth and multiplication (reproduction) of the plant.

The cytoplasm stores most of the food substances. For example sugars and starches are stored in the cytoplasm to maintain the life of the plant. Cell is also made up of vacuoles. In some cells, the vacuole contains a watery solution called the <u>cell sap.</u> This sap contains mostly mineral salts absorbed from the soil. But in other cells, the vacuoles act as a channel

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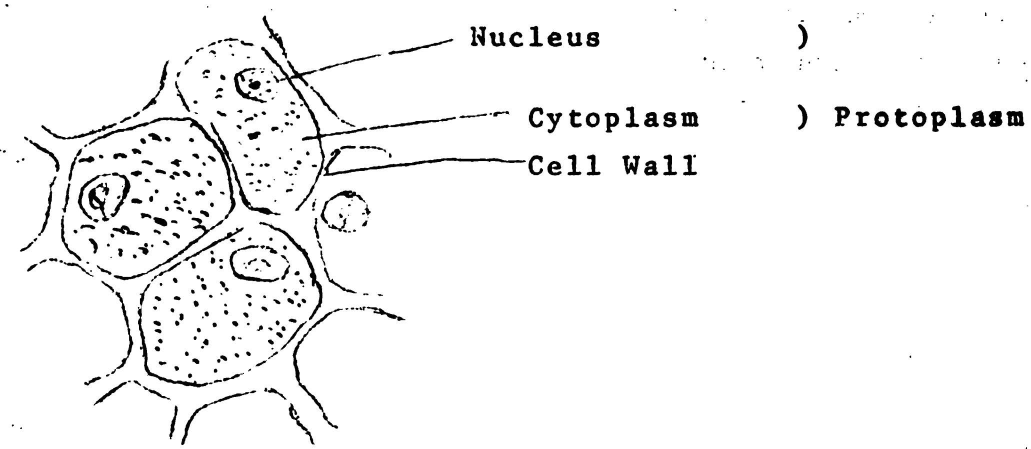


A geoup of highly magnified plant cells

through which various substances in the plant passes. Embedded in the cytoplasm are also small bodies called plastids. These contains the pigments which gives the plant its colour. Chlorophyll is the green pigment found in plants and is contained in plastids. These green plastids are called chloroplasts. The green parts of the plant have cells in which there are many chloroplasts. The cell is surrounded by a cell wall. It is these walls that give cells their shapes and act as a skeleton which gives the different organs their rigidity and shape.

A GROUP OF HIGHLY MAGNIFIED PLANT CELLS.

Groups of cells within the plant form the tissue. Then, it is the tissues that make up the organs of the plant. The cells are so organized within the various organs to perform different functions. For example, the cells in the root hairs allow water and other liquid substances to pass through their walls. Another group of cells known as the xylem acts as a channel, taking the liquid through the stem and to the leaves. Yet another tissue known as the phloem allows food that is manufactured in the green portion of the plant, to be transported to other parts of the plant. Each plant is made up of millions of cells.

Function of plant parts

(1) The SHOOT:-

The stem support and spaces out the leaves so they can get adequate air and sunlight. The leaves need sunlight and air to manufacture food. The stem also conducts water and dissolved mineral salts from the root to leaves. It also helps to carry food formed in the leaves back to the root. There it will be used to provide energy for the roots to grow while some may be stored. The leaves are the organs in which most of the food is manufactured. But they also have pores through which the plants breathe. The plant also gets rid of excess water (i.e. transpiration) by way of these tiny openings on the surface of the leaves.

The buds are the growing points of the shoot. This is the point where young leaves are produced. The flowers are special kinds of buds which the plant produces for reproduction. These specialized buds are the organs which develop into fruits and seeds.

(2) The Root:-

The root absorbs the food substances from the soil. The soil and the atmosphere are the two sources of food for the plant. Minerals e.g. nitrogen, phosphorous and potassium are absorbed by the root hairs when the minerals are dissolved in water. The solution formed, passes from the cells of the root, through the stem and into the leaves where it is used to make food. The root also anchors the plant to the soil and helps to transport the absorbed nutrients to the shoot.

Chapter 3 LIFE OF THE VEGETABLE PLANT

The life of the vegetable plant like all other Seed Plants have three main stages:-

Germination

Growth

Reproduction

The vegetable plant is a complete living body or organism. It is grown as food for man. Because of this, in some crops, the life of the plant is terminated before it enter or complete the final stage. For example, life of cabbage plant is ended during growth while cauliflower is allowed to enter but not complete its reproductive stage. It produces the flower, but is not allowed to produce seeds. The plant in which their fruits and seeds are eaten usually complete its life cycle. eg. Kidney beans.

A. GERMINATION - THE BEGINNING OF A NEW LIFE

This is a process during which the young shoot and root emerges from the seed. The seed consists of a tough outer coat or testa which encloses the embryo. The embryo is made up of a plumule which will develop into the shoot and a radicle which will develop into the root. The embryo might be enclosed in 2 cotyledons (dicotyledons) or embedded in a single cotyledon (monocotyledon).

It is the cotyledon (s) which contain the food that the plant will use when its root and leaves are too young and poorly developed to absorb minerals and other nutrients to produce its food.

During germination, the main processes that take place within the seed are:-

(a) Absorbtion of water.

(b) Conversion of the food material stored in the cotyledons into a soluble form that can easily supply energy to the embryo.

(c) Utilizing of the converted food substances to form new cells which develop into the plumule and radicle.

(d) Growth of the cells, the plumule and the radicle.

CONDITIONS NECESSARY FOR GERMINATION

Certain conditions are necessary for germination. They are:-

Good seeds
Adequate moisture (water)
Adequate Oxygen and suitable temperature

1. <u>Good Seeds</u>

It should be fairly easy to understand that the seed must be good for it to germinate.

<u>A good seed is one that is-</u>

Viable -

(a) ie well developed with mature embryo and cotyledon (s) storing enough food to maintain the young plant during the germination process.

(b) Disease-free ie the seed has no disease neither within or on its testa. When germination occurs the disease, if present, will affect the seedling. Leaf spot disease on peas, and black leg on beet and cabbage are examples. Diseases destroy the protoplasm- ie. the living substance in the cells of the seed. Without good seeds the farmer does not have a crop.

ADEQUATE MOISTURE

Vegetable seeds require adequate moisture for germination. The amount of water in the soil (or any medium in which the seeds are to germinate) should not make the medium too wet or too dry. It is important to note here that different seeds will germinate in different moisture conditions. Example- The seed of Corn, cabbage or turnip will germinate in almost dry soil, while peas, beet or lettuce need a more moist medium. Celery requires almost soaking wet soil. The water enters the seed and causes it to swell and burst the testa so that the young plant will emerge. Where water is inadequate, the chemical processes which occur within the seed will not take place. In addition, the seed will not absorb sufficient water to split the testa. On the other hand, too much water might exclude the amount of air required in the soil for germination.

ADEQUATE OXYGEN AND SUITABLE TEMPERATURE

During germination like any other stage in the life of a plant, for the chemical processes to take place certain substances and certain conditions must be present. Water is one such substance and oxygen is another. But the reaction of these and other substances must take place within a certain range of temperature. Temperatures within the range of 40-100°F (5-38°C) is required for the germination of most vegetable seeds. Neither oxygen nor temperature usually poses a problem to the tropical grower. These are adequate for germination throughout the year.

DO ALL SEEDS [illegible] THE SAME TIME TO GERMINATE?

Seeds of different crops usually take different times to germinate. This is a natural situation that is in the genetic (inborn or inherited) make up of the plants. Corn, tomato, peas will germinate within 10 days, while pepper or parsley might take 2 or as much as 3 weeks. This is the genetic trait passed from one generation to the other.

But the same crop might also take different times to germinate when the same seeds are planted under different conditions. The most frequent cause of this in the tropical regions is a difference in the amount of moisture in the soil, For all crops, seeds will germinate more quickly, as the amount of moisture increases up to a point. Above this point, water will be in excess and the soil will be soaking wet. Here the seed would not germinate because of inadequate supply of oxygen. After some time, the seeds themselves would rot.

(3: 2)

(a) Watering seed-beds after planting (b) corn germinating (c) pea germinating

GERMINATION COMPLETED

The emergence of the plumule of the young plant usually completes germination. The radicle has developed into a young root having small secondary roots. By then, these have started to absorb minerals and water from the soil. The plumule bearing its first leaves are now exposed to light. They become green and start to use the minerals absorbed by the young roots to manufacture their own food. The plant is now ready to enter its second stage - growth.

Percentage germination (%G)

Percentage germination refers to the amount of a given quantity of seeds that is viable. This amount is expressed as a percentage of the given quantity. (When this quantity is not expressed as a percentage, it is called germination capacity).

Learn this formula -

$$\% G = \left(\frac{\text{number of germinated seeds}}{\text{number of seeds planted}}\right) \div 100$$

B. GROWTH - (LIFE CONTINUED.)

The vegetable plant, having completed its germination, pushes its first young leaves above the surface of the soil. Most plants have two leaves then. After a week, the same plant might be 2 or 3 inches (5 or 8 cms) tall with 3 or 4 leaves, and within a month, 2 or 3 feet(2/3to 1 metre) tall with 30 or 40 leaves. The plant has grown. This growth results in the increase in the size of parts of the plant as well as the formation of new organs. It takes place throughout the entire life of the plant.

How Does The Plant Grow?

The small units or cells of the plant are responsible for its growth. It does this in two ways -

1. Each cell might increase its size by stretchi ng its walls. This is called cell elongation and may be due to increase uptake of water and, or, increase in the amount of protoplasm within it. But each cell can grow to a certain size and no more. The plant also uses a second method,

2. Cells in the buds, root-tips and most organs with young parts have the power to multiply or reproduce themselves. In this, the single cell divides to give rise to two cells. Each new cell will later divide to give rise to two other new cells and so on. This second method is largely responsible for the rapid growth of the young parts of vegetable plants. It is a division process that has a multiplying effect, Hence it is called cell division or cell multiplication.

(3: 3) (a) Plant 2 weeks old. (b) Plant 4 weeks old. (c) Plant 6 wks old.

What causes the plant to grow?

Cells enlongate and multiply for the plant to grow. But this is due to a number of processes taking place within the plant. These give the cells and the whole plant the power or energy for each cell to multiply and the whole plant to grow. A study of these processes taking place within the plant is known as plant physiology

The vegetable plant in many ways resemble a factory and like most factories its functioning is not an easy one to understand. It is not easy as each process taking place in the factory is complex and more than one might be going on at the same time.

In the plant, the whole physiology is centered on -

Breathing - intake of CO_2 and release of O_2.

Absorbtion - (uptake of raw material or plant nutrients from the soil.

Photosynthesis - (manufacture of food from these raw materials).

Transpiration - (release of excess water absorbed from the soil).

Respiration - (breaking down and using the manufactured food).

C. BREATHING -

Plants breathe through the leaves, stems and roots. Vegetable plants do most of their breathing through tiny pores (stomata) in the leaves. The carbon dioxide (CO_2) which they breathe in, is used in photosynthesis. Oxygen (O_2) is given off during this process. Animals provide most of the CO_2 that plants get from the air, while the plants provide animals with the O_2 which they breathe in.

D. ABSORPTION - SUPPLYING RAW MATERIALS

Plant Nutrient -

The vegetable absorbs or takes in substances called plant nutrients or plant food elements. There are fifteen such elements which are proven to be essential to the growth of seed plants.

The elements are taken from the air, water and soil. Those taken from the soil are divided into 2 groups according to the quantity of the elements that the plant requires for its growth and reproduction.

(3: 4)

Elements from air and water	Elements from the soil		
	Major elements		Minor or Trace elements
	Primary	Secondary	
Carbon (C)	Nitrogen (N)	Calcium (Ca)	Boron (B) Manganese (Mn)
Oxygen (O)	Phosphorous (P)	Magnesium (Mg)	Copper (Cu) Molybdenum Mo)
Hydrogen (H)	Potassium (K)	Sulphur (S)	Iron (Fe) Zinc (Zn)

The plant food elements in the soil are mixed with other elements as salts (mineral salts) and must be absorbed before it can be utilized. They are absorbed in a solution.

Mineral Salts + Water → Solution

The root hairs of the plant are in contact with the solution containing the nutrients. The water passes through the walls of its cells into the root hairs, (by a process called osmosis) through the secondary roots to the main root. In monocots the solution passes directly from secondary roots to stem. Certain inner cells within a layer of tissue surrounding the xylem and phloem exerts a pressure on the outer cells. This root pressure helps to pull in the nutrient solution from the soil. The xylem vessels then conducts the solution from root, through the stem into leaves.

The other essential elements from the air are absorbed through the stomata on the leaves and stems. Thus, breathing and absorbtion provide the raw-material used by the plant to manufacture food.

Conditions that affects absorbtion of water from the soil are:-

1. Soil temperature
2. Availability of water in the soil.
3. Supply of air in the soil.

These factors will be discussed fully in a later chapter.

E. PHOTOSYNTHESIS

Photosynthesis is the process by which food is manufactured in the plant. The plant food elements in the green parts of the plant are utilized in the presence of sunlight. The sunlight supplies the energy which is absorbed by the green pigment of the plant - chlorophyll. Other substances known as enzymes play a very important part in this and all other chemical reactions in the plant. These enzymes are catalysts, therefore, they can speed up the rate of photosynthesis. Some enzymes are made up entirely of proteins and therefore consist of Carbon (C), Hydrogen (H), Oxygen (O) and Nitrogen (N). But some have both a protein and a non-protein portion or co-enzyme for its functioning. The elements copper, zinc, manganese, magnesium and iron are all found in different co-enzymes. Some of these enzymes take part in photosynthesis.

The equation of Photosynthesis:-

$$6\,CO_2 + 6H_2O \xrightarrow[\text{in chlorophyll + Enzymes}]{\text{+ Enzymes energy from sunlight}} C_6H_{12}O_6 + 6O_2$$

The equation says that carbon dioxide(CO_2). combines with water (H_2O) in the presence of chlorophyll and enzymes to form a sugar-glucose ($C_6H_{12}O_6$) and oxygen is given off.

<u>Transpiration</u> - A part of the water absorbed by the plant is utilized directly in photosynthesis. Most of the water however, passes through the xylem vessel and helps to keep the plant 'cool' since some of the chemical reactions in the plant generate heat. Most of the water to be used in photosynthesis is tored, and water which is not used, leaves the plant mainly through the leaves as water-vapour. This is <u>transpiration</u>.

The food stored by the vegetable plant is the same food eaten by man when he eats vegetables.

Types of food:

There are 3 main types of food substances found in all Seed Plants, but different vegetables contain each in different amounts.

(1) Carbohydrates - This group consists of the sugars and starches. The simple sugar glucose which is manufactured in photosynthesis, acts as the basic unit for the formation of more complex sugars. Sucrose, found aboundantly in sugar cane, is one example. But these complex sugars can be further converted in the presence of enzymes, into more complex substances-starches. It is in this form that most vegetable plants store the products of photosynthesis. Watermelon is rich in sugar, while potato is rich in starches. Both crops contain plenty Carbohydrates.

(2) Protein- These are synthesized from the sugars manufactured in photosynthesis. In the building of proteins, the nitrogen absorbed by the plant, is used to form the amino-acids, that make up proteins. Although C-H-O-N are the main elements that make up these amino-acids, most of the other essential elements are also found in proteins. Sulphur and Phosphorous occur in some proteins. Others were mentioned in relation to co-enzymes. The plants store some of its food as proteins. The seeds of most legumes are rich in this food.

(3) Fats - These are found in various parts of the vegetable plants, but is most often concentrated, like proteins in the seeds of most crops. Soya bean, peanut and corn are all seeds and fruits which store considerable amounts of fat. However, compared to carbohydrates, the amount of proteins and fats produced by the plant is very low. For in most plants, fats and proteins form less than 10% of the dry matter that make up the plant. But in some vegetable seeds, fats and proteins for about 35% of the total dry material. The basic unit of fats are the fatty acids which contain C-H-O- and are synthesized from the sugars made in photosynthesis.

(4) Vitamins - These are found in minute amounts compared to carbohydrate protein and fats. Most vegetables contain one of more of the 15 or so vitamins that are known to exist. For example, tomato is rich in vitamin K, while the leafy vegetables supply A,B and K.

Carbohydrates, Proteins, Fats and Vitamins are all needed by man for healthy living.

USE OF MANUFACTURED FOOD

Food substances manufactured in photosynthesis are:-

(a) Used to supply energy for growth and reproduction,

(b) Stored for later use in leaves (eg cabbage), stem (eg. kohl-rabi), roots (eg. carrot), fruits (eg. cucumber) and seeds (eg. beans).

F. BALANCING RAW MATERIAL

For maximum food production during photosynthesis, the plant must maintain the correct balance between each element absorbed. This is important since the plant has to absorb and utilize the quantities of nutrients in a given proportion for optium synthesis and growth. Imbalance of nutrients can be due to a insufficient amount of the nutrient in the soil or in a form which is unavailable to the crop. It may also be due to the plant absorbing excess of one or more nutrients which supress the uptake of another element. Examples - An excess of Ca due to use of large amount of calcium material or other reasons, can cause the crop to suffer from Mg deficiency even when sufficient Mg is in the soil. An excess of K can also depress the uptake of Mg and visa versa. Imbalance among the primary nutrients can also be due to an excess or deficiency of nutrients. Excess of N can cause leaves to grow very rapidly, But these leaves may be flabby and easily susceptible to diseases while the stem and root of the plant are poorly developed. This could be due to the excess N supressing the uptake of P,K and other nutrients. Hence food production cannot be at a maximum.

Why imbalance?

Each element in the correct amount creates a balance or equilibrum in the uptake of elements. Let us look at what happens when this balance is upset. An element may unbalance the system and prevent maximum production in two ways - i.e. when it is in too large supply (excess) or when it is in too small an amount (deficient).

Excess of a nutrient is something that hardly occurs, compared to elements in short supply. When it occurs, it is usually after a deficiency. The grower in trying to correct the hunger, applies too much of that element. Sometimes also if a particular crop is grown with the same fertilizer for many crops, an excess of a nutrient may exist in that soil. For example, growing leafy vegetable with high Nitrogen fertilizers for several crops on a clayey soil, can result in excess of N.

The plant shows imbalance of elements usually in 2 ways-

(1) Abnormal growth conditions on whole plant or its parts, eg. stunted growth, discoloration and certain diseases.

(2) Reduced production.

We will discuss this some more later.

Photo

Photo

(3: 5)

(a) Stunted growth is the most common sign of excess or deficiency of nutrients

(b) Blossom end rot in water mellon is die to nutrient Imbalance.

Because of the larger quantity of primary elements used by the plant, a deficiency of these elements is more common than of secondary elements. The same is also true of an excess because the grower in trying to correct the deficiency might now add too much primary elements. Fertilizers are commonly used to supply plant nutrients, hence application of large quantities of fertilizer containing primary elements might create the imbalance. The watermellon in (b) shows a deficiency condition due to insufficient calcium, in the plant. This might not be due to inadequate Ca in the soil, but rather an excess of [illegible] one element supressing uptake of [illegible]

[illegible]

Large quantities of P, Ca, Mg and S can generally have little direct harmful effect on the plant. High concentration of N & K, because they dissolve easily might damage the tissue of the plant, but these elements are not known to be toxic or poisonous to the plant. The minor elements ie B, Cu, Fe, Mg, Zn and [illegible] are directly toxic in too high [illegible]

Listed below are the essential elements, their chemical functions and general deficiency symtoms (or hunger signs), as shown in the growth of the plant. Notice the relation between the functions of the nutrients and their signs of deficiency. (3: 6)

Elements		Functions in plants	Signs of deficiency
Carbon Hydrogen and Oxygen	(C) (H) (O)	- parts of all sugars, starch, fats (C-H-O)*and proteins(C-H-O-N)*	This seldom happens as long as plants are grown in the open and get water.
Nitrogen	(N)	- part of all proteins(C-H-O-N) including enzymes	-slow and dwarf growth with fruits reduced in size
		- part of chlorophyll (C-H-O-N-Mg)	-pale yellow leaves.
Phosphorous	(P)	- part of enzyme (invertase) in converting starch to sugar.	-Slow growth and production and fruits take long to mature.
		- part of substances ATP that stores energy in cells (ATP-adenosine triphosphate)	
		- part of substances formed in photosynthesis and respiration (phosphoglyceric acid)	
Potassium	(K)	- necessary for the manufacture of simple proteins(amino-acids)	-Reduced production
		- helps plant to absorb the amount of water required	-Reduced growth and curling or drying or of leaf margins.

* This shows the elements present in these substances and is the method used throughout this book.

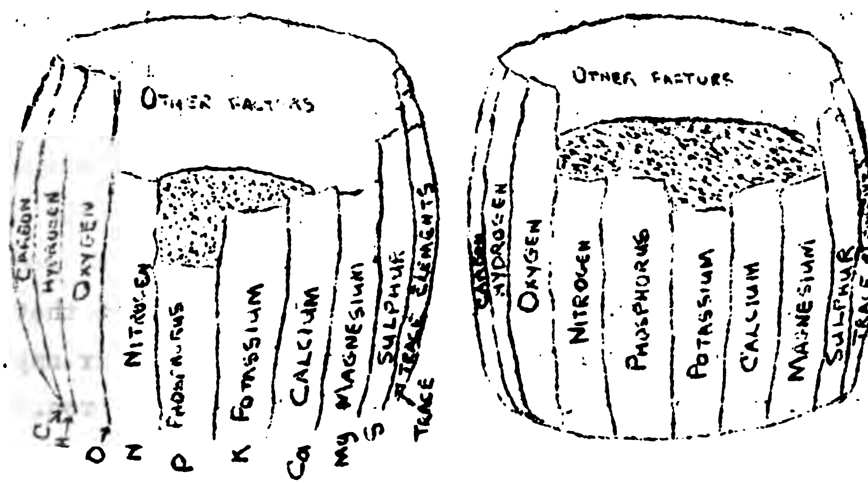
Elements	Function in plants (contd)	Signs of deficiency (contd.)
Calcium (Ca)	- helps plant to absorb N - part of substance (Calcium pectate) in cell wall. - react with poisnous substances in cell, making them non-toxic.	Light green bands along margin of leaves.
Magnesium (Mg)	- important part of chlorophyll (C-H-O-N-Mg) - part of substance (magnesium pectate) in cell wall that enable it to stretch.	Leaves become yellow in patches (mottling) Stem brittle or break easily.
Sulphur (S)	- part of some simple proteins (eg Cystine) - important in manufacture of new protoplasm - helps plant to take up N	Plant stunted with slender stem. Yellowing of older leaves
Manganese (Mn)	- increase amount of Ca, Mg and P available to plant	Leaves smaller than normal, few fruits formed.
Boron (B)	- helps plant to use Ca - important for cell division.	Stem tend to crack <u>or</u> parts of plant rot.
Copper (Cu) & Iron (Fe)	- part of an enzyme in manufacture of chlorophyll	Pale green leaves in presence of adequate N.
Zinc (Zn)	- important in chlorophyll formation	White buds of some crops.
Molybdenum (Mo)	- helps plant to use N	Yellowing between veins of older leaves.

A close look at the table will show that all the essential elements are included. The elements have to be present in the plant in the correct quantities for the plant to manufacture food at the optium (or maximum) level and to use this food for optium growth.

Law of Minimums

The law of minimums stakes that:-

The yield of a crop (or a single plant) is limited by the deficiency of any one necessary element although all others are present in adequate amounts.



(3: 7) (a) Phosphorous - a limiting factor (b) Phosphorous Supplied- Potassium becomes next limiting factor

The two above diagrams illustrate the law of Minimums......

In the diagrams, the total amount of water the barrel could hold if all staves were at the top, represents the maximum amount that the crop or a particular plant is capable of producing (ie maximum productive capacity). Each element is a single factor that can affect the production of that plant. A factor in short supply is a limiting factor ie it limits the amount that a plant can produce.

(Note- other factors that affect yields include water, temperature, sunlight, soil conditions).

In (a) phosphorous is a limiting factor. The barrel cannot hold more water because the phosphorous stave is so low compared to the other staves.

When P is applied in (b), K becomes the next limiting factor. It is the lowest stave and although the barrel can now hold more, it cannot hold the maximum that it has the capacity to hold.

Whether or not all these factors can reach the top of the staves (i.e their optium level), we do not know. But what we do know is that all vegetable growers should try to supply each factor to the best of his ability so that his crops will go as near to maximum production as is possible.

Minimums - How come?

Let us continue to look at the single vegetable plant, and assume that all plants in a crop behave in more or less the same way. So, whatever applies to the single plant, we will assume that it holds for the entire crop.

Remember that any one element if not in the correct amount can upset the balance required for maximum growth and production. Look back at table 3:6 showing the function of each plant element.

N as limiting factor.

We will assume that adequate supplies of secondary and trace elements are present in the soil but not all primary elements in the required amounts. The plant has all the P and K it requires but N is deficient. Then, it has all the P it needs to form enough invertase that it would require in converting starch to sugars for producing energy. It also has enough P to form ATP for storing the energy. The plant also has the K it would need to manufacture proteins from sugars. But, where is the starch that the invertase will act on or the K will help to change into proteins?

It is not present in the quantity needed for optimum growth and production. The Nitrogen is not sufficient to form the amount of chlorophyll needed nor is it adequate for the maximum protein that the plant has the potential to produce. Without the required amount of chlorophyll, there cannot be maximum growth and yields. Nitrogen, is the limiting factor.

A similar situation would occur with adequate N and P and low K or adequate N and K and low P. Because if K is limiting, there would be enough chlorophyll for optimum food manufacture, but the maximum amount of protein could not be formed.

Mg as limiting factor

Now let us assume that all 3 primary elements and the minor nutrients are present in sufficient amounts, but there is a secondary element in short supply. Let us make magnesium (Mg) the deficient element.

The vegetable plant would have all the other elements it requires for maximum growth and production. But first, it cannot produce the required amount of chlorophyll. And secondly, if it even had the amount of chlorophyll, when it manufactures the food, where would it store this food? Deficiency of the substance magnesium-pectate causes the cell wall to be poorly developed. They cannot stretch to store the food. The result is that this acts as a brake which prevents the plant from forming food at its optimum. We might think that a single factor preventing the proper functioning of the whole plant is a selfish act, but that is how it is Mg acts as a limiting factor on growth and production.

Ca as limiting factor.

Let us look at calcium as the element in short supply with all other elements each in the quantity required for maximum food production. Without enough Ca, the plant cannot absorb sufficient N to manufacture the amount of chlorophyll or later, the maximum amount of proteins. But in addition, for optimum food production, each leaf blade (upper surface) should be fully exposed to sunlight. Now the plant does not have enough calcium-pectate in its cell walls, as a result these walls are not fully developed. So that older leaves are twisted and the young ones sometimes do not open to be fully exposed to sunlight. Ca becomes a limiting factor as it prevents the fullest uptake of sunlight (energy) for highest rate of growth and production.

(3: 8) (a) <u>Left - leaf blade fully exposed to sunlight</u>.

(b) <u>Right - twisted blade prevents maximum sunlight</u>.

By this same method, we can show how any single element in short supply can limit production. Think of another primary, a secondary and a trace element in this way, and see how the law holds for each. Try P,S and Fe for a start,

G. RESPIRATION. - (Energy for life).

Respiration is a chemical process in which energy is produced from the manufactured food material. This process is sometimes called an oxidizing reaction because it is one in which Oxygen reacts mainly with glucose (a simple sugar) to produce the energy. Water and carbon dioxide are also given off. The process is almost the exact opposite of photo synthesis.

$$C_6H_{12}O_6 + 6\,O_2 \xrightleftharpoons[\text{Enzymes}]{\text{Enzymes}} 6\,CO_2 + 6H_2O + \text{Energy}$$

The energy released is the energy taken in from the sunlight during photosynthesis. But the plant cannot use it directly, so it is stored in the food to be later released by oxidation. When man eats the food, he takes into his body this energy which is also released by respiration in his body. During this process the substance A T P (adenosine tri-phosphate) is formed and it releases the energy easily when the plant requires it. (Note the phosphorous in ATP. Insufficient P to form ATP naturally cause stunted growth due to lack of energy.)

Stages in Respiration

We can divide the whole process of respiration into 3 stages, namely-

1. - food conversion
2. - food redistribution
3. - energy production.

The 3 stages follow one immediately after the other to form a continuous process.

1. Food conversion - The breaking down process is most active in the absence of sunlight. This usually at nights when the building up process (photosynthesis), is least active or is not taking place at all. The food manufactured in the green parts is converted to simple sugars and redistributed throughout the entire plant.

2. Food redistribution - These sugars are transported to the lower parts of the stem and the roots through the phloem. This channel is made up of cells adjoining each other and runs beside the xylem throughout the plant.

Remember that the xylem is the channel that carries the raw material absorbed by the roots to the leaves for food production. The phloem on the other hand transports the manufactured product. If we always bear in mind the resemblance of the vegetable plant to a factory, this becomes easy to grasp. Because those of us who have some knowledge of factories would know that most have certain channels. Usually one set of channels that carry raw material and another set that carries the finished product.

So that, during the night, most of the starch is converted to simple sugars and later transported to all the living cells of the plant.

3. Energy production - It is in each living cell that the O_2 taken into the plant through the pores or stomata of the leaves is used to oxidize the simple sugars and the ATP is formed. The ATP will store the energy until it is needed by those cells.

(Note that when the plant takes in O_2 from the air, this is breathing and not respiration).

How is the energy used

1. The energy released during respiration is used by the plant in all its life processes . Most is used during growth.

2. While most is used in growth, some is stored as food in the fruits and seeds used for reproduction. So that when the plant forms its fruit and seeds, it has merely stored up the energy in the form of starch, sugar, proteins, fats and minerals that make up fruits and seeds. This energy will start the next germination of plants when those seeds later germinate for the next crop of vegetables.

GROWTH HABIT

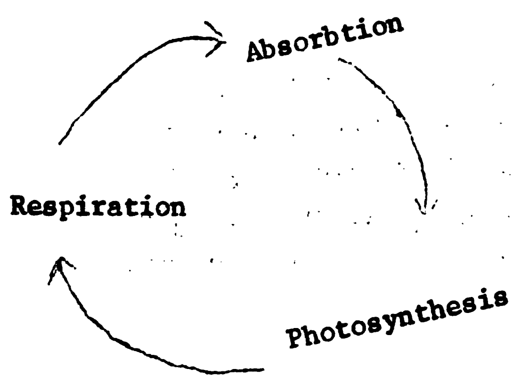
While the metabolic processes (i.e. absorbtion, photosynthesis, respiration) takes place in basically the same way in all vegetable plants, the plants of different crops have different growth habits. The growth habit of a plant (or crop) describes the overall way in which that crop grows. It includes -

1. - Measurement of growth i.e. height and diameter of the plant at different times during the crop.

2. - Growth description i.e. general description of features like, time to germination, flowering, fruiting, first and final reaping.

Because these are taken from plants which are individual members of a particular crop, (samples), we usually talk about the growth habit of a crop and not individual plants. Later we will see where knowing the growth habit of a crop can be used for many purposes by the vegetable grower.

H. SUMMARY OF GROWTH - A cycle



The 3 processes form a cycle Trying to determine which is first, is make trying to find out if the egg comes before the chicken. We merely go on in circles.

Without photosynthesis, the plant would have no food to provide the energy for respiration or for absorbtion. But without respiration it would have no energy for absorbtion, but it had to absorb to get the raw material for photosynthesis. So its the question of who is first - chicken or egg.

The Vegetable grower and the Cycle

The question of what is first is not important to the vegetable grower. What is important is that his plant carry out these three (3) processes. Without his plant carrying them out - it is dead. It is for the grower to ensure that the plant has what is required to absorb nutrients, manufacture food, and utilize it for further growth.

The vegetable grower must try to supply:-

1. adequate plant nutrients.
2. enough water so that the plant can absorb the nutrients.

He must also supply these with the correct methods. A field of cabbage might require 100 lbs N - fertilizer. The grower if he does not use the correct method of application - (if for example he allows it to fall on the plant and in between the leaves,) might damage the crop and make it worst off than before.

I. REPRODUCTION

To reproduce as the name shows, means to produce again or simply to produce another. Reproduction is therefore the process the plant uses to produce other plants of its kind. When a tomato plant reproduces it produces other tomato plant in the same way that man reproduces, he produces another man.

Methods of Reproduction

Vegetable plant reproduce in 2 ways -

1. Asexual method - (meaning not sexual) In this method a part of the parent plant is planted and a new plant grows from this part.It is also called vegetative reproduction.

2. Sexual method - In this, a male and a female cell unites and develops to form a seed. These cells are found in the sexual part (flower) of the plant. The seed will germinate to form the new plant. This is by far the more common form of reproduction.

ASEXUAL REPRODUCTION

Vegetative reproduction is hardly used in vegetable production, apart from a few crops like potato in which the stem-tuber, (called the seed by farmers), and sweet potato in which a portion of the stem is planted. Propagation (another word for reproduction) of most crops is done by seeds.

Methods of Asexual Reproduction

1. Cuttings - The most common method of vegetative reproduction is by planting a part of the plant in a rooting medium. The part is called a cutting. This might be set directly in the field or set in a building called a plant propagator. Here, it can be adequately supplied with moisture. Substances known as rooting hormones may be used to speed up the formation of roots. After roots are suitably developed, plants kept in a propagator are transplanted into the field,

(3: 9) Sweet - potato can be grown from cuttings.

2. Tubers - These are swollen parts of the plant that store food. When the stem is the storage organ, it is called a stem-tuber (eg. irish potato) and when the root, it is a root-tuber. (carrot, beet)

Potato is grown in vegetable production mostly from stem tubers that are commonly refered to as seeds. Some varieties can also be easily grown from cutting of parts of the foliage.

(3: 10) Irish Potato tubers

3. Layering - A part of the stem is made to produce roots while still attached to the parent plant. When the roots are developed, the portion bearing the root and the remainder of that branch is cut off from the parent and planted.

We can bend a young branch and, peel off (7.5-15 cms0
a portion (o 3-6 ins.) of its bark and cover that part in soil of good drainage. This is soil layering.

Or, the peeled off portion /can be surrounded by a fibrous material (eg. coir) and the whole thing covered with plastic and tied at both ends. The plastic should have a few small holes to allow that part of the stem to breath. The medium should be kept moist. This is air layering or circumposing.

(3: 11) Circumposing

4. <u>Budding</u> - A bud from one member of a family is placed beneath the bark of another member of the same family. The branch can be cut in a number of different ways to take the bud which also has to be cut to fit. The area with the bud is carefully bounded with plastic tape. Dry banana raffia, can be used to give fairly good results. The binding is made to keep out as much water as possible out of the wound, but at the same time, allowing breathing. Too much water would prevent cementing of bud and stem, which is necessary for the stem to supply the bud with nutrients.

(3: 12) <u>Budding</u>

After the bud has grown to a certain size, the portion of budded branch which is above the bud in addition to those branches not budded, are cut off. Each bud is allowed to develop to form the new plant. Note that more than one bud can be placed on a single plant. The new plant will now bear fruits of the plant from which the bud was taken. If some branches that were not budded were left, the plant would produce two types of fruits. Some of us might have seen this in some, plants like mangoes and oranges.

Egg - plant (garden egg) can be used to bud susumber (gully beans). Both belong to the Solanaceae or Tomato family.

(5) Grafting - A portion of a branch (usually the top 6") from a member of a family is used to replace a similar part removed from another plant of the same family. It is very similar to budding except that a part having many buds, instead of a single bud, is used.

Importance of Asexual Reproduction

Vegetative propagation as a whole, and layering, budding and grafting, in particular, are seldom used on a large scale in vegetable production. However, farmers and students should experiment with this method to see if it can be used on a large scale. This is so as new plants very closely resemble parents. For example we plant a field of egg plant, some plants will produce fruits with a range of quality. This would be reduced if plants were propagated vegetatively from parents producing fruits of the desired quality.

We will understand the importance of this to the grower, when we study about grading vegetables.

SEXUAL REPRODUCTION

Stages of Reproduction

Sexual reproduction is a continous process, but takes place in stages. These stages are:-

- Flowering
- Pollination
- Fertilization
- Fruit and Seed Formation.

J. FLOWERING - (The First Stage.)

What is flowering?

Flowering is the period during which the vegetable plant produces its reproductive organs - the flower. The flower contains the male and female structures. In some plants, the flowers bear only male or female organs on each flower and are said to be uni-sexual, eg pumpkin. Most plants bear flowers with both male and female organs on each flower. They are said to be bi-sexual eg tomato. In this way plants also resemble animals, in that some animals especially the higher animals including man are uni-sexual. So we distinguish man from woman.

How are flowers borne?

Each flower might be borne on a separate flower stalk (eg. pea, okra) or a group of flowers on a single stalk. This is called an inflorescence. When one eats a head of cauliflower, one is eating an infloroscence. Lettuce also produces an infloroscence, but corn is a more familiar example.

Structure of Okra flower

The okra flower is familiar to the vegetable farmer. It might not be so with the student grower, as what is usually familiar to him in tropical regions is the hibiscus. The okra and the hibiscus belong to the same family - malvaceae and their structures or the organization of the various parts is simple and easy to understand. The okra flower shows the general features of most dicotyledonous vegetable plants. Not all flowers, have all the parts or have them organized as in the okra. In corn and other grasses for example, petals are completely absent, while in some plants, three, five or more petals may be present. The same is true for the other parts of the flower. The reader should try to get hold of an okra or hibiscus flower as we discuss the parts.

Parts of the flower

There are four main parts of the flower:-

(1) Sepals (2) petals (3) stamens (4) carpels

(3: 13) (a) Complete flower of okra (b) Half-flower of okra

In fig. (a) the complete flower and its main parts can be seen, while in (b) the half-flower is an easy way of showing the structure more clearly.

Sepals - These are small modified leaves which are most important in protecting the young flower or bud.

Petals- The petals are usually of bright colours when they exist. The petals of the okra, usually of bright yellow, attracts insects which suck nectar from the flower. The insects help to ensure that the male reproductive cells (pollen) reach the female part of the flower.

Stamens - These form the male part of the flower. Each stamen consists of a stalk or filament at the top of which is the anther. The anther contains the pollen in what are called pollen sacs. The pollen grain or germ cell is the male reproductive cell. Reproductive cells are called germ cells because they develop into the embryo or germ that will germinate to form the new plant. (They do not cause "germs" or diseases in animals and should not be confused with those organisms).

Carpels - These are the female reproductive parts of the flower. They contain the female germ cells. A flower might contain one or more carpels, which may be separated or joined together. Okra has one carpel made up of the stigma, the style and the ovary. The ovules containing the female cells are within the ovary. The whole ovary will develop into the fruit while the ovules into the seeds.

Note - The sepals collectively make up the calyx; the petals; the corolla; the stamens; the androecium and the carpels together are the gynaecium.

Another flower   Corn.

The structure of the flower of corn is in many ways different from that of okra. The flowers form an inflorescence but each is unisexual. The male flowers are small with no petals or sepals. The absence of petals is the reason why some people usually believe that this plant does not produce flowers. But we should remember that all vegetable plants bear flowers. So the corn has its male flowers separate from the female ones, and they are carried by the plant on the tassel, at the apex of the stem. (The tassel is commonly called the flag).

The female flowers are borne further down the stem and forms the ear of the corn. The silks on the ear are fine thread-like structure looking like the hair of some human beings. Some people passing corn fields jokingly pull them out and put them in their heads. Pulling out the silks is not good for the corn as the corn silks are the styles bearing the stigma of the flower. Without the stigma, the fruits cannot be formed. Each silking ear has a cob surrounded by leaves on the ear. Attached to the cob are the young undeveloped seeds. Each seed is really a fruit.

(3: 14) The flowering corn.

(i) flowering plant   (ii) tassel   (iii) silking ear.

(iv) young ears with leaves removed to show young fruits on cob.

K. POLLINATION - (The second Stage)

In the vegetable plant, during pollination, the male cells or pollen, is transferred to the female part of the flower via the stigma. We can say that this process is the sexual intercourse of the plant.

Types of Pollination

In vegetable plants, the transfer of pollen might be effected in 2 main ways viz, - 1) - self-pollination. 2) - cross-pollination.

1) Self-pollination - In this type of pollination, pollen from a flower will fall on the stigma of the same flower and pollination occurs. The plant is said to be self-pollinated. eg. beans.

2) Cross-pollination . In this, pollen from one flower will be carried to the stigma of another flower of the same or another plant of the same crop. The plant is said to be cross-pollinated. This pollen might be carried by insects - (i.e. insect pollinated flowers*), or by the wind - (i.e. wind-pollinated flowers*).

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* Note that these names are misleading as they suggest that the flower is pollinated by insects or by the wind. We must always remember that it is the pollen and not the insects or wind that pollinates the flower. These names are used in this book as some students might be already familiar with them.

Okra and cucurbits are examples of insect pollinated flowers, and bees and wasps are the chief agents of pollination. This is why a vegetable grower must be careful that in spraying to control insects damaging his crop, he does not spray insects that are agents of pollination.

The corn and all grasses are examples of wind-pollinated flowers. If a person walks in the corn field after early tasseling and the wind is blowing or the individual touches the plants, the yellow powdery material falling, is the pollen. Wind-pollinated plants produce considerable more pollen than insect pollinated ones, but only a small quantity actually pollinates a flower. When the pollen is carried by the wind, it is not as sure as to reach the stigma of another flower as when carried by insects. By producing this large amount, it ensures that the whole crop will be pollinated. Excess pollen is usually seen on the ground or on leaves of the corn and weeds in the field.

(3: 15)

Here are some crops and the way they are pollinated.

1. Self-pollinated	2. Cross-pollinated		
	(Insect-pollinated)		(Wind-poll.)
Beans	Cabbage family	Ckra	Beet
Endive	Cucumber family	Onion	Corn
Lettuce	Celery	Parsnip	Spinach
Tomato	Eggplant	Parsley	Swiss chard

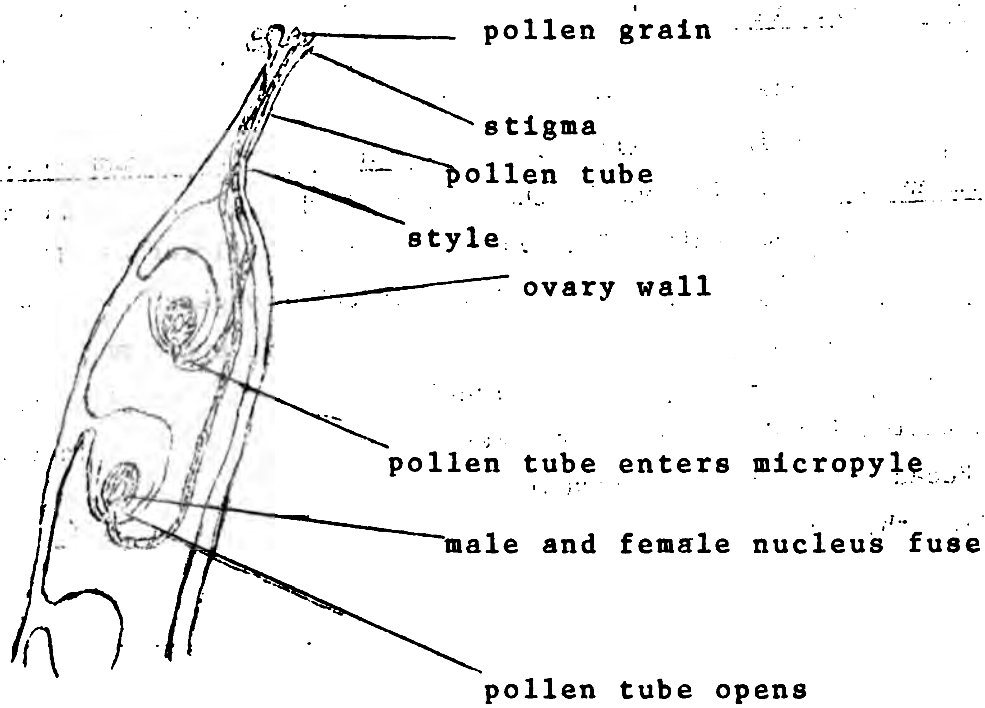


Diagram of fertilization

FERTILISATION. - (The Third Stage).

What is Fertilisation*?

Fertilisation follows pollination with the interval between the two different with the crop. During fertilisation, the male and female germ cells are united to form an egg. This is done by the fusion of the nucleus of the male and female cells in the ovule. The ovule is fertilised and each will develop into a seed containing the developed egg or embryo.

Pollination is necessary for fertilisation, but, a flower might be pollinated but fertilisation does not occur. Here again the vegetable plant resembles man. Because in man, after sexual intercourse, the sperm may or may not fertilise the female cell.

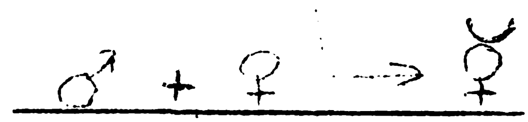


Diagram illustrating. Fertilisation.

Each pollen grain is a cell with a nucleus. The ovule also contains the nucleus of the female cell. Each pollen grain deposited on the stigma, will absorb nutrients from the stigma, and send out a pollen tube. The pollen tube carries the male nucleus (♂) into the ovule where the nucleus from a single pollen grain fertilises the female nucleus (♀) in the ovule.

The egg that is formed is now ready for further development into the embryo (⚥) that will give rise to the new plant.

M. FRUIT AND SEED FORMATION - (The Final Stage).

Fruit Formation.

After fertilisation, petals, stamens, stigma and style wither and usually fall. The plant starts to store food for its next generation. Some of the food it manufactures, will be stored in the fertilised flower. The ovary starts to enlarge rapidly, so fast in some crops that growers are often caught in surprise. Within a week from flowering, the fruits of some plants might be developed enough to be ready for reaping. Okra is an example.

The development of the fruit and storing of food is merely to aid in the development of the seeds. Different plants will store different amounts of the food substance in their fruits. Cabbage store a lot of starch while the watermellon stores a lot of sugar. It is the type and amount of food that the vegetable stores in its fruit which makes it important.

Onion stores food in its leaves, potato in its stem, while beet and turnip store its food in their roots. These parts are not fruits. The plants store their food in leaves, their stem or root because their fruits usually do not store much food. They can also reproduce vegetatively using these storage organs.

Seed Formation

At the beginning of seed formation, the fertilised ovule in the ovary will enlarge. It further develops and each ovule will form a seed. The plant also stores food in its seeds, which will be used in germination. So the whole ovary develops into the fruit, provides protection and food supply until the seed is fully matured.

Conditions necessary for fruit and seed formation

Conditions necessary for proper fruit and seed formation are very similar to those required for growth.

(1) Adequate supply of water and nutrients.

(2) Suitable temperature and day length

1. Water and nutrients. - These two factors must be in the correct balance for proper fruit and seed formation. For example, a high supply of water at fruiting might make a fruit watery and of poor taste. This shows itself quite clearly in watermellon. However, this same condition might also be due to lack of phosphorous in the soil. Poor water supply makes the fruit withered and spongy, but this can also be caused by deficiency of pottasium in the soil.

These conditions more often cause fruits to be deformed. Deformed fruits might not be poorer in taste or quality, but less attractive. In most countries today, appearance is as important, if not more important in many ways than what the product really is. The vegetable grower must always bear this in mind. His crop must have the conditions for the highest yield of fruits, the highest quality and most attractive appearance.

(3: 17) Deformed fruits of cucumber

(1) (2)

(3) (4)

(5)

2. Temperature and day length - is not as serious for the tropical grower as in temperate regions. But certain crops will neither flower nor fruit if certain seasonal conditions do not exist. We will discuss this some more under cool season and warm season crops.

The final stage and the vegetable grower

This stage might seem to be of greatest importance to the vegetable grower. It is this stage that made him plant the vegetables in the first place. The flowering stage is important to him, but not because he likes to see beautiful flowers; these grow in his flower garden at home. There he plants hibiscus and not okra. But the grower might also note that although this stage is most important to him, without proper care of his plants at flowering, he might be worst off than if he planted hibiscus on his farm. For if he carelessly moves through his field during flowering and bounces off the flowers, his labour and his spendings on growing the crop might be unprofitable. He might be in more trouble than with his flower garden.

SUMMARY OF LIFE - Another Cycle

The life process of the vegetable plant - germination, growth and reproduction is the second cycle we have discussed so far. The first one was in growth-absorbtion, photosynthesis, respiration and we would be going in circles if we should try to say whether absorbtion was before photosynthesis or photosynthesis before absorbtion.

(3: 18)

The same is true of the life process of the vegetable. If the 3 processes of growth form a cycle and the 3 stages in the life of the plant also form a cycle then the growth stages form a lesser cycle while life forms the greater cycle.

The seed planted will produce a new plant via Germination. The new plant will develop into a mature plant in which case it now becomes old via Growth. The old plant then produces new seeds via Reproduction. The new seeds will then be planted to start a new cycle - new cycle?? or new cycle within an old cycle. New or old for the vegetable grower and for all mankind - the cycle must go on.

Chapter 4

VEGETABLE PLANT AND SOME RELATIVES

An organism is a living body. There are two main types (viz plants and animals.) We will look at some organisms which directly affect the life of vegetables. Among the plants are - bacteria, fungi and viruses, while among the animals - worms, insects, farm animals and man.

A. BACTERIA, FUNGI AND VIRUSES

These plants live freely in soil, water, air and decaying material. They are simple in structure with the bacteria having only one cell. They contain no chlorophyll and therefore cannot manufacture their own food from CO_2 and H_2O. They depend on other bodies for their food. When they get their food from dead bodies, they are called saprophytes. (This does not apply to virsuses which can live and reproduce only in living plants or animals)

It is for this reason that when a part of the vegetable plant is damaged and dead cells are in that area, the bacteria and fungi will attach themselves there. In a short time they will feed in this area and cause that part to decay. As they feed and grow, the damaged area will increase in size until that part or the whole plant is killed. More often however, the plant is killed by those that attack its living parts.

Diseases

Bacteria, fungi and viruses cause diseases which are usually observed when the effect of their feeding results in damage to the plant. They also produce substances which are poisonous to crops. These organisms multiply quickly and it is for this reason that disease spread so rapidly.

(4: 1) Diseases caused by bacteria, fungi and viruses.

Quite often, by the time the grower observe the disease, it has spread so far that it might be impossible to control. To control diseases caused by viruses is extremely difficult. Most efficient control is therefore by adapting methods to prevent the action of these organisms.

How diseases are spread

Diseases are spread when the organism or its reproductive unit (spores in fungus) is carried from a diseased plant to a healthy one. This can be carried by:-

(1) Wind
(2) Running water eg. irrigation water
(3) Movement of equipment or individuals from disease to healthy plants.

This third method is most important for the vegetable grower to note. A common means of spreading tomato diseases is by using a knife to prune an unhealthy plant, then use it on a healthy one .

(4) Some diseases are carried from one generation to the other by seeds eg. black-leg.

(5) Some diseases are also spread by insects which feed on an infected crop, then a healthy one.

Are all these organisms harmful?

Like relatives, not all of these organisms are harmful. The most common example of beneficial use is the nitrogen-fixing bacteria. These play an important part especially in legumes in adding nitrogen to the soil. They get the nitrogen from decaying plants and animals and from the atmosphere. This is an important part of the process known as the <u>nitrogen cycle</u>.

B. WORMS.

There are two types of worms we will look at as being important in our study of vegetables. They are - (i) earthworms (ii) a type of round-worm called nematodes. We should not consider organisms like armyworms and corn ear worms - (two organisms which damage most crops), as worms. Each is really a larva of an insect and not a worm. Earthworms are found in cool moist soils on which it feeds and then egests the remains on the surface. Nematodes that are harmful to crops live in soil but some may also be found in fresh and salt water. Unlike earthworms, they are so small they cannot be seen with the naked eye, microscopes have to be used.

Effects of Earthworm

Like man, the vegetable plant has good relatives, and bad ones. The earthworm seems to be more of a good relative. They are helpful to the plant in 2 main ways viz 1. In feeding on the soil, these worms dig small tunnels through the soil. These improve the movement of air in the soil. We must remember that 0_2 is needed in the soil for the roots to breathe and their cells to respire.

2. The feeding habit of the worm also improve the movement of water in the soil. Later we will see that improving drainage is one of the key means of getting better yields from vegetable crops.

Effects of Nematodes

Most nematodes are harmful to the vegetable plant. The harm they do is mainly by direct attack on the plant which is its source of food.

1. They enter the roots of the plant and being parasites, they reduce the growth and production of each plant. In extreme cases, when in high concentrations in the soil, the crop will be badly infected. Many parasites feeding on a plant, cause rapid loss of manufactured food. Soon, the plant wilts and later dies. However, because parasites do not usually kill the organism it depends on for its food (i.e. the host), nematodes more often cause reduced yields.

   (By the way, why do you think parasites do not usually kill their hosts?) Kill your host and you are dead! Apart from directly robbing the plant of its manufactured food, nematode attack on vegetable plants might cause-

Root Knots

2. Root knots or root galls - These are enlarged portions of the root caused either by the feeding of the worms in that area or the fact that they are enclosed in the galls. These areas are usually spongy or woody with few and deformed secondary roots. (See photo).

3. Root lesions - These are portions of the root which have collapsed due to the feeding of the worms. The lesion is usually discoloured and might increase in size quite rapidly.

4. Excessive root branching or damaged root tips - These are most harmful to the vegetable plant because it affects nutrient uptake thereby reducing growth and production. Often, damaged tips will later develop into root rots. This occurs when bacteria or fungi invade the damaged areas and later the whole root will rot away. In some cases, the centre of the main root will rot or shrink leaving a hollow root without its secondary roots.

Control of Nematodes

Because nematodes can do such extensive damage, the vegetable grower must try his best to rid his soil of them when they occur, or at least control them. Like bacteria, fungi and viruses, they can be spread by wind blowing infected soil into areas free of the organisms. More often, they are spread on the vegetable farm by irrigation water, or the movement of land preparation and weed control implements. Control measures include -

1. Improve practises eg. crop rotation in which crops that are not readily attacked by the worms, are planted in infected areas. Corn is one such crop. This should be used as a supplement to other means of control.

2. Chemical Control i.e. applying certain chemicals (called nematicides- eg. nemagon) to infected soil.

3. Flooding - i.e. flooding the infected soil for several months which is supposed to drown the nematodes. Most need free oxygen for breathing and if they are deprived of this for any considerable time they die.

C. INSECTS.

Insects are lower forms of animals that are found on land, in the soil and in some cases in water. They are generally small (usually less than 2 ins long x 1 in across) but take a number of sizes and forms within this range. There is little need to go into much details as to what insects look like. Most tropical people are familiar with insects from catching butterflies or stumbling on wasps nests. Insects like all other organisms, feed on plants including vegetables. It is for this reason we study them in this book.

General Structure -

Insects are more or less enlongated and cylindrical in form. Their bodies are segmented with each segment, shown by a distinct marking on the outside of the animal. The segments are grouped into three reigons viz.

1. The head - bearing the eyes, antennae and mouth parts
2. The thorax - bearing the legs and wings (when present)
3. The abdomen - which bears no distinct organs for movement, but have some appendages at its apex.

(4: 3) Diagram showing the general structure of an insect (Grasshopper).

The body of the insect is made up of a number of systems. The organs by playing their different functions and working in coordination, makes it possible for the animal to carry out its life processes.

Parasitism and predation

Parasitism - Some insects get their food at the expense of other insects. They get this food in two ways. First, some live in or on the bodies of larger insects, and get their food from these insects. The one which supplies the food is called the host, while the feeder is called the parasite. Although the insect feeds on the host, it does not readily kill its host. One can easily see that this is wise, as killing the host might be detremental to the parasite itself. This is true whether the parasite is a worm or an insect.

But these parasites sometimes feed on hosts that are insects and that do serious damage to vegetable crops. Although the parasite does not readily kill the host insect, by robbing food, it cuts down considerably on the reproductive powers of the host.

Predation The other relation is one in which a larger and stronger insect (predator) feeds on small insects (prey). When the predator feeds on the insects harmful to vegetables it is doing a great service to vegetable production. The two feeding habits are one of the chief reasons why despite the speed at which insects can reproduce, they have not been able to destroy most of mans food. It's the usual story - " one insect keep down another insect". This is called biological insect control.

Life of insects.

Insects during their life time passes through a number of distinct stages. these are:-

(a) egg (b) lava (c) pupa (d) adult

Each stage is of different duration, and during each the animal changes its form. The stages through which insects pass from egg to adult is called metamorphosis. Some insects pass through these 4 stages (complete metamorphosis) while others do not do this. Butterflies have complete while the grasshopper, for example, have incomplete metamorphosis. In the latter, the egg hatches into a nymph which later grows into the adult.

Brief description of life history -

Complete metamorphosis, starts with the young insect in the egg develops and is hatched. When hatched, they do not resemble the adult, but are like worms. They are called larvae, worms, maggots or catapillars. These should not be confused with true worms (eg. earth-worm, nematodes) which remain worms when they are adults. The larva is the feeding and growing stage in the life-history. It is for this reason that they do so much damage to vegetable crops.

When the larva is fully grown it becomes inactive and then neither feeds or moves. It is then called the pupa. Changes take place within the body of the pupa as the adult organs are formed. The pupa develops into an adult.

(4: 4) (a) Incomplete metamorphosis of grasshopper (b) Complete metamorphosis of butterfly

The student of vegetable production should be familiar with different insect pests and their life history. Most important is that the student should be able to identify the larva as distinct from the adult. In some cases, some-one not familiar with these forms might be misled in applying control methods. For example, in a cabbage field attacked by diamond-black moth the adult will be seen flying around. A grower who is not familiar with the forms of the insect, might direct his energy in trying to control the adult. But the adult does little damage as most is done by the larva on the underside of the leaf. The adult is merely there hatching the eggs, so that by the time the grower sees the adult and tries to control it, thousands of eggs would have been layed on the crop. Controlling the adult would not prevent the eggs from hatching into larva. It would be like closing the gate after the horse is gone through it.

Harm and Help

Some insects are helpful to the vegetable plant, while others are harmful. Despite the difference, the way the insect helps or harms , is directly related to its feeding habit.

1. Helpful in pollination - As we have seen earlier, pollination is a necessary step in reproduction of all vegetable plants. Remember also that in some plants (eg. corn) the pollen is transfered by the wind (wind-pollinated flower) while in others, this is done by insects (insect-pollinated flowers). Bees and wasps are the most common examples of insects which help in pollination of vegetable plants. It is enough to say that

plants which produce insect-pollinated flowers would have a hard time if not impossible to reproduce without insects. They carry the pollen from one flower to another when they move around feeding on a sweet juice (nectar) produced in these flowers. So that it is the feeding habit of insects that make them act as an agent of pollination.

2. Damage plant parts - Insects are so harmful to vegetable crops that most growers forget that they are helpful in some ways. Although it can do great-harm to forget that some insects are beneficial it is treacherous to forget how much injury they can do.

   Insects feed on the fruits, leaves, stem roots of vegetable plants. This is the damage most easily seen by the grower although at times it is seen only after considerable damage has been done to the plant. All insects do not feed in the same way, and in most cases, they feed according to the structure of their mouth parts. They have two main types of mouth-parts, viz-

   (a) Chewing mouth- parts - The insects with chewing mouth parts (called chewing insects) bite off bits of the plant part. The effects of their feeding habit is easily seen on the damage they do to foliage. In some cases, the damage is not done by the adult insect, but by its larva. The bean beetle and most beetles are examples of adults while army-worm and mellon worm are examples of larva with chewing mouth-parts.

   (b) The insects with piercing - sucking mouth-parts (called sucking insects) pierce the plant part and sucks the sap from the plant. The sap is the liquid substance of the cell most of which is water with plant elements in solution. Some of these insects (eg. scale insects) attach themselves to the plant and move slowly from one part to the other in absorbing food. Others (eg. aphid) move from one plant to the other. Later we will see that this feeding habit, not only rob the plant of nutrients but also helps it in spreading diseases.

The damage done by sucking insects is not as readily seen as in chewing insects, but both injure the vegetable plant and reduce production.

Internal feeders - These are insects which tunnel their way into the plant parts. Their damage is similiar to chewing or sucking insects, but are particularly known for the damage they do to fruits. Leaf miners are the most common example of internal feeders on leaves. Wire-worms are known for tunnelling into roots and stems of a number of crops. The corn stalk bore as its name suggest seems to have a special taste for the stem of corn.

3. Attack stored food - Insects damage not only crops in the field, but also the stored product. Corn and legumes because they are often stored for long periods are regular targets. The group of insects known as weevils do considerable damage this way. The adults are greyish brown or black beetles (approx 1/4'-1/2' long) (3/4 - 1 1/2 cm) while the larva are large white worms with dark heads frequently found in rotting wood.

4. Transmit diseases - Insects are one of the chief agents in spreading diseases. This they do when they feed on an infected plant then a healthy one. This the insects do whether they have chewing or sucking mouth-parts. The aphid is particularly known for the large number of diseases it spreads.

D FARM ANIMALS

These animals are most important, in that they eat the vegatable plants and return some of its nutrients as manure. Cow, poultry, horse, goats are important source of manure supply on many small tropical farms. Later, we will discuss manure in more detail, but for the present, we should note that they help to supply nutrients to the soil. Manure from different animals have different compositions. For example, poultry manure is rich in N while cow manure has usually about half the amount of N but about the same proportion of K.

Apart from supplying organic manures, farm animals can consume some of the " left-overs" from the vegetable farm and help to provide needed income especially for the small vegetable grower. Some farm animals also help with transporting supplies to and from the farm especially where roads are poorly developed.

E. MAN

The vegetable plant as food

The plant in general is the chief source of food for man. Even when he eats animals, he is indirectly eating plants. The sugars, starch, proteins fats and minerals are the products of photosynthesis of the plant. It is for this reason that man grows plants and vegetables which are rich in these substances. In most countries vegetable production is increasing.

But man is most important in relation to the vegetable because he usually controls to a certain extent, the conditions under which they grow. He clears the land and removes the natural shade from the vegetables. This increases evaporation from the soil. Man must put back this moisture for maximum growth and production of the plant. This is usually done by irrigation or trying to cover the soil artificially with mulch. The same is also true of other practices. Most important however is that men terminate the lives of most vegetable plants before they complete their life cycles. This is why it is important that he plants seeds of the highest quality to ensure that he maintains the vigour of the life he has cut short. His rapid removal of crops before they die and shed their leaves to add nutrients back to the soil means that by artificial means or otherwise he must return these elements in the correct amounts. Without this he is going to hamper the process of photosynthesis, respiration, growth and later reproduction.

Chapter 5 THE VEGETABLE PLANT AND THE SOIL. Section 2.

A. What is soil?- Soil is a mixture of particles of rocks, decayed plants and animal matter, air and water. Soil is the natural medium in which plants usually grow. All vegetables are usually grown in the soil, but it is important to know that some plants grow in water as a natural medium.

How are soils formed?

Soil formation is a very slow process. Different types of soil take varying periods to be formed. Most times it takes hundred of years to be formed from its parent material. Different types of soils are formed from different parent materials and sometimes in different ways. To begin with all inorganic or mineral soils are formed from rocks, while organic soils usually are formed from decayed plant material. But in each case, the process is slow and passes through many stages.

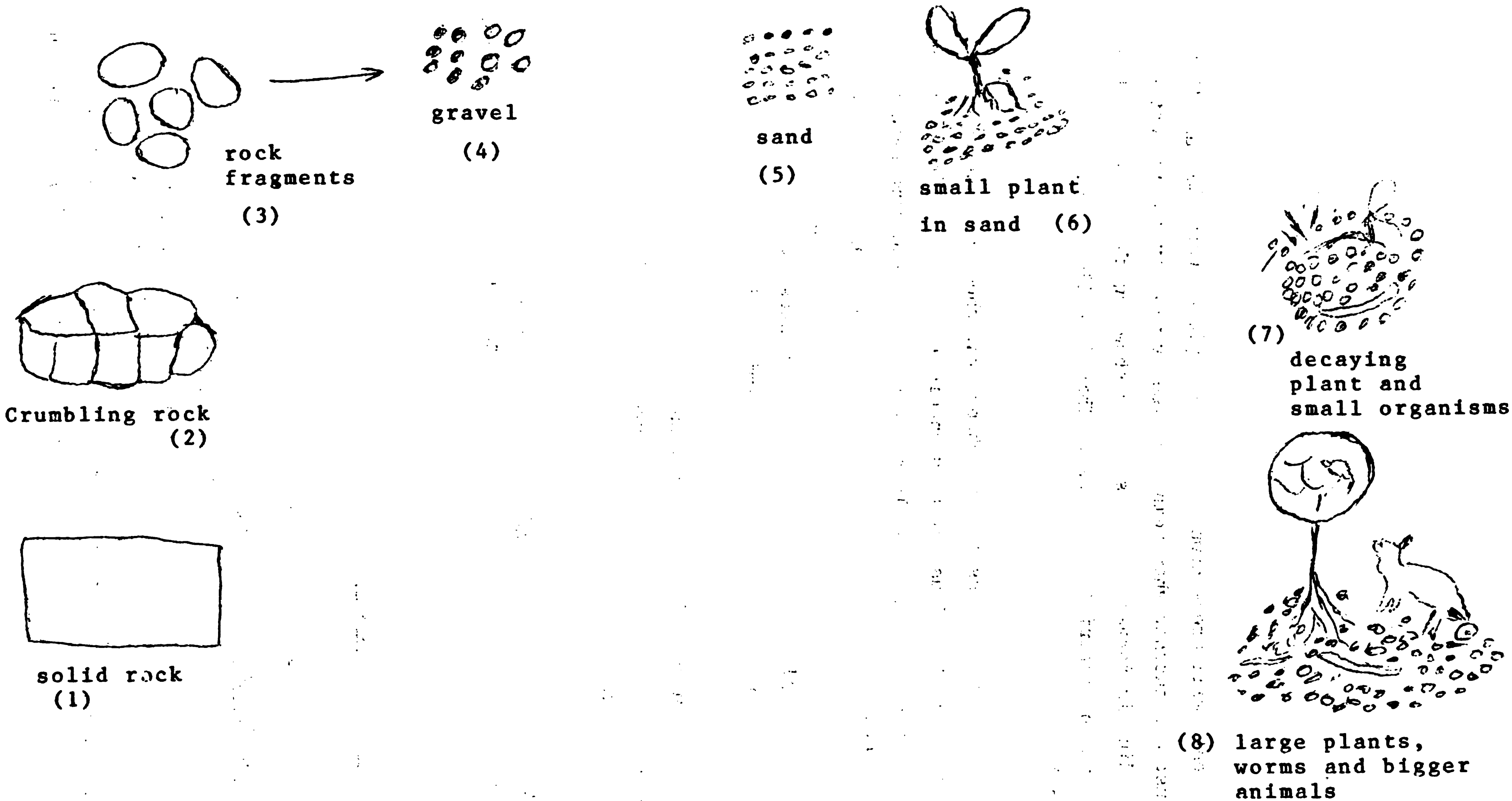
Most soils are mineral soils. They are formed mainly by the process called weathering. (Stages 1 to 5)

The steps in soil formation

1. Solid rock is the material from which soil is formed. Different types of rocks will weather and form different types of soils.

2. When exposed to the heat of day and coolness of night over a period of time, the solid rock starts to crack. Roots of trees may grow into the cracks and help to further crack and split the solid rock material.

3. Rain water helps to soften the area between the cracks, and the big boulders break into smaller fragments. This material which is neither solid rock nor soil, is called the parent material.


rock fragments (3)
gravel (4)
sand (5)
small plant in sand (6)
(7) decaying plant and small organisms
Crumbling rock (2)
solid rock (1)
(8) large plants, worms and bigger animals

4. Rock fragments will break down into smaller pieces (gravel) as they rub against one another, when being carried by wind or running water. A sandy medium is formed. (Stages 1 to 4 show how the physical make-up of the parent material is changed. This is called physical weathering)

5. Water and air helps to dissolve and change the chemical make-up of the rocks. It is mainly because of this chemical action (chemical weathering), why different types of soils are formed from the same parent material.

6. Spores of simple plant life, like algae and mosses, will fall in the sand. Seeds of small plants will also germinate in the sandy medium.

7. Small plants when they die will decay and add organic matter or humus to the soil. Small worms and other organisms will feed on the dead plants and live in what is now soil.

8. Larger plants and animals - worms and other organisms, birds and farm animals will be able to eat/ plants on this soil. When they die, they add more humus.

<u>What are the functions of the soil?</u>

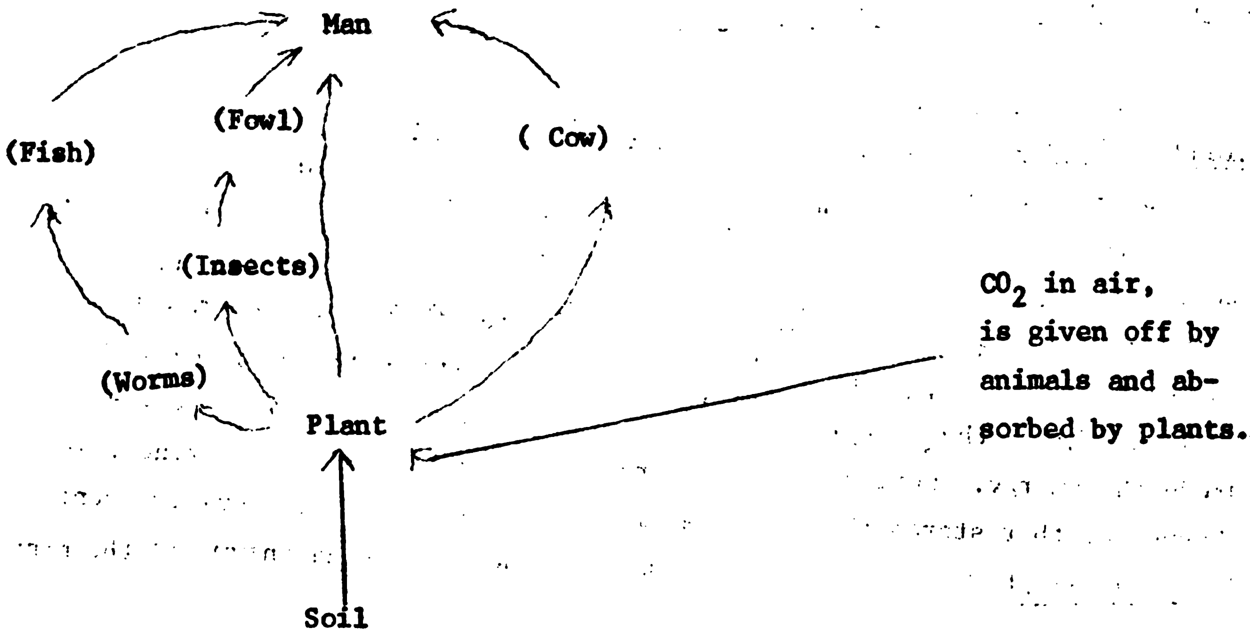
The soil serves 3 main functions. These are:-

1. <u>Provide physical support</u> - soil supports the physique or the body of the plant. This it does by acting as an anchorage ie. the medium in which the plant anchors itself. The roots form the anchor.

2. <u>Supply plant food</u> - it supplies some raw material or essential plant nutrients used in food manufacture - (photosynthesis) eg nitrogen.

3. <u>Acts as resevoir</u> - from which the plant draws its water using the roots. The soil contains air from which the plant will get the oxygen it needs to break down manufactured food to supply its energy (respiration). This energy the root will need to use in absorbing water and nutrients and for growth.

Sources of food



(5: 3) All food comes from the soil and the atmosphere

Whenever man eats food he indirectly eats the nutrients from the soil and the atmosphere. The diagram (fig. 5: 3) above explains this. The arrows indicate where the food comes from and if the words "supply food to" were written along each arrow, it would make the picture clearer.

The foods supplied by vegetables - sugars and starch contain carbon (C) hydrogen (H) and oxygen (O) while proteins and fats contain C, H, O, and nitrogen (N) in addition to other elements.

Vitamins are found in small amounts compared to sugars etc, but man also requires only a small amount in his body compared to the other foods. Most trace elements taken from the soil are found in these vitamins.

Elements from soil and the atmosphere are in the body of man.

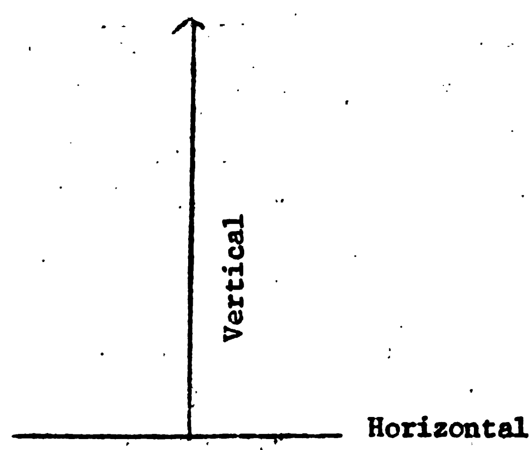
The alements taken in the food are found in different parts of the body of man. C, H, O, N, are found as proteins in most of the flesh of the body. Phosphorous (P), calcium(Ca) and magnesium (Mg) are found in the bones of the body. Iron(F) is a part of the haemoglobin - the red substance in blood that carries the oxygen to various part of the body for producing energy. Here again phosphorous is a part of ATP (adenosine triphosphate) that stores the energy as it did in plants, Copper (Cu) is found in the liver where it is stored and used in the body as an enzyme in the manufacture of haemoglobin.

What is soil profile?

A soil profile is a vertical section from the soil surface to the parent rock material from which the soil is made.

(5: 4)

(a) Photo or diagram of a soil profile



(b) Vertical and horizontal lines

When a toilet pit or a tank is dug, until solid rock is reached, each side form top to bottom represents the soil profile. The same is true of the banks of newly cut roads in hilly areas where portions have to be cut through soil surface down to rock.

Horizons -

The profile is made up of horizontal layers. Each layer is called a horizon. Undisturbed soil has 3 horizons - A, B and C.

Horizon A is called the surface soil or top soil. It is usually darker in colour because of the presence of more humus in this layer and is rarely more than 9-12 inches (23-30 cms) thick. Because it is on the surface, it is the layer from which vegetables and all plants take most of their nutrients. The vegetable grower has to take greatest care of this layer.

Horizon B is called the sub-soil. It is lighter in colour than the top soil, because of less humus. It might have loose gravel and sandy material especially near to the parent material. This layer might be a few feet thick or nearly a hundred feet thick depending on the soil type and where it is located.

Horizon C is the layer of parent rock material. This layer is made up of soft rocks or fragments of different sizes. How deep down it is will also depend on the type of soil and where it is located. In hilly areas, this horizon is usually near to the surface than on the plains even with the same soil type. There is no clear line that marks off one layer from the other. There is a zone between each layer where one merges into the other. The three horizons resemble various stages in rock formation. Try to see which layer of the soil resemble. What stage of soil formation.

Soil depth - Its importance

Two kinds of soil depth are important to the vegetable grower.

1. The first is depth of the top soil. The vegetable plant takes most of its food material from this layer. Therefore, if this layer is thin (less than 4-6 ins) (10-15 cms) the amount of nutrients will be limited. The grower will also know that he might have to apply more nutrients as fertilizers and more water, than if the top soil were deeper. Deep-ploughing (over 12 ins) (30 cms) would have to be avoided because it would continually bring up poorer sub-soil to the face.

2. Depth of top soil, sub-soil and its importance.

The second measurement of depth that is important is <u>the depth of the</u> sub-soil. This will directly influence the type of crop that will grow most easily on the soil. Soils that are over 5 ft. (1.5 metres) in depth of top and subsoil can be regarded as deep soils are less than 2 ft. (0.6 metres) and soils of 2 to 5 ft. (.6-1.5 metres) as moderately deep.

- 0
- 1'
- 2'
- 3'
- 4'
- 5'

Observing the figure (5:5) would show that cabbage can be more easily grown on a shallower soil than would turnip or tomato. The person growing vegetables should know this. Vegetables should be grown on moderate or deep soils. Few will do well on shallow soils and even then they will need plenty water and manures.

(5:5) Roots of cabbage, Turnip and Tomato

<u>Hard-pan</u>: Sometimes the soil is deep, but roots of plants cannot penetrate below a certain depth. This is most common on clay soils and is due to an impervious layer (not easily penetrated) at this depth. It is called <u>hard-pan</u>.

Apart from preventing growth of roots, it might also prevent water from sinking into the sub-soil, ie. it prevents proper drainage which will reduce the production if it does not kill the plants.

Special equipment called chisels attached to tractors can penetrate up to 18 inches (45 cms) below the surface and used to break up hard pans.

Maintaining the soil profile

The vegetable grower in clearing his land and ploughing it, is tampering with the natural condition of his soil. By clearing he is removing the covering which protects the soil from running water and wind. Ploughing loosens the top soil and cut roots that hold soil together. It can be easily washed or blown away. Removal of soil in this way is called erosion. Wind and running water are the main agents of erosion.

Types of erosion

There are 2 main types of erosion:-

1. Sheet erosion - in which soil is removed in thin layers over an entire area of land. When rivers overflow their banks on to open plough lands nearby, rapid sheet erosion occurs. More often it occurs slowly and much of the top soil might be removed over a period of time without the grower noticing. It is particularly dangerous to vegetable growers on slightly sloping land.

2. Gully erosion - in which the running water forms a small stream, digs a ravine which grows as the size of the stream develops. Soil is also removed rapidly, but is easily seen. Erosion is not confined to top-soil, but might occur through the whole soil profile if not checked.

Controling erosion - The grower cannot prevent erosion. As long as wind blows and water runs, soil will flow. He cannot prevent it, but at least he can control it. When the vegetable-grower farms, in particular/on loose soil, he looses money. Sometimes when soil is washed away it carries plants with it.

How to control erosion

1. Avoid regular ploughing of soil on steep slopes or any soil type that erodes easily. Plant permanent crops instead of vegetables.

2. Terracing - ie. growing the crops on flats made with the soil along the contour (areas of same height) of the slopes. Each flat is called a terrace and the terraces on the slope resemble a flight of stairs. A rise separates one terrace from the other. Grass or stone walls might be at the edge of the riser with a permanent crop planted on the riser.

3. Contour ploughing - ie. ploughing along the contours of the slope. Furrows are also made along the contours. The crop is also planted along the contours.

4. Strip cropping ie. - growing the crop on alternative strips of ploughed and unploughed land. Grass can be planted on the unploughed strips and this prevents washing of soil from onestrip to the other.

5. Mulching ie. - covering the soil mainly with plant material (eg. dry grass). This prevents the soil being exposed/directly to the effects of wind and rain.

How important is soil temperature?

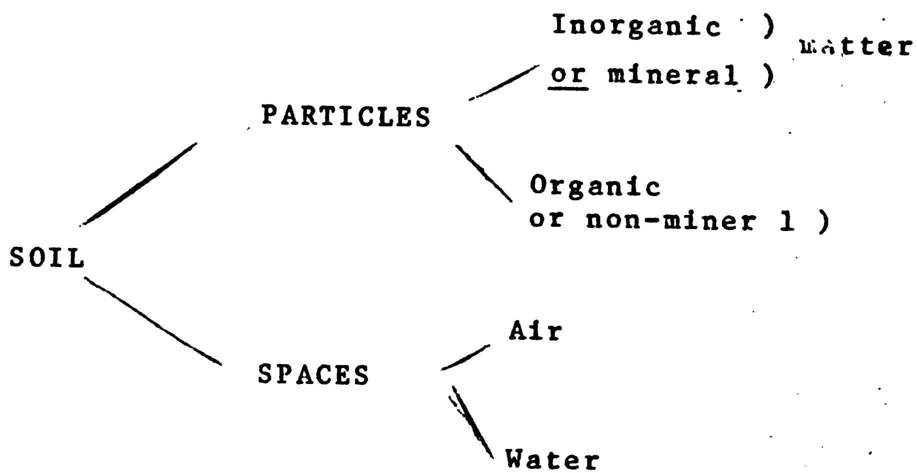
For vegetables, not only is the temperature of the atmosphere important in its production, but also the soil temperature.

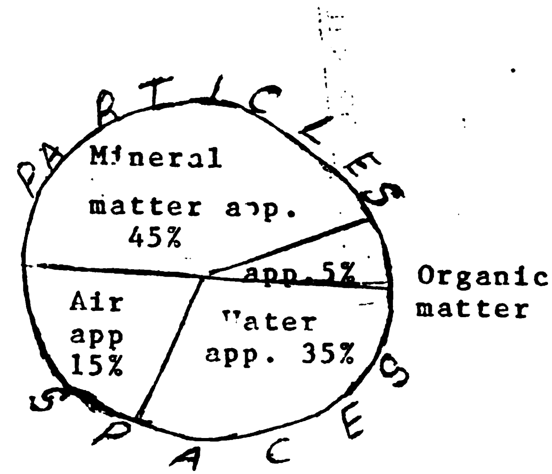
1. Seeds of each vegetable crop, will not germinate outside a certain range of soil temperature. This is so, as germination is a chemical process which requires certain temperatures. For example, beans require soil temperature of between 65 -85°F (18-30°C) while eggplant needs between 75 - 90°F (24 - 32°C). In most tropical areas, because we do not have the problem of freezing soils at any time of the year, most seeds will germinate throughout the year.

2. The root of the plant requires warmth to carry out all its metabolic activities.

Parts of the soil -

An outline of the parts of the soil follows:-





B. FEATURES OF THE SOIL

Parts of the soil

An outline of the parts of the soil follows.

Fig. (5: 7).

Soil is made up of particles between which are found spaces. The particles form the basic frame-work of the soil and is made up of inorganic or mineral matter and organic matter or humus. (In a heap of oranges the oranges form the basic framework of the heap with spaces between the oranges).

I norganic matter

This is usually the largest single constituent of the soil and is formed from weathered rocks. The colour and chemical make up of the soil depends largely on the type of rock from which the mineral matter is made. For example, soil derived from rocks rich in iron (iron oxide - Fe_2O_3) tend to be red in colour. This is why bauxitic soils are usually red as they are 'rich' in iron. They are usually richer in another in-organic substance known as aluminia (aluminium oxide, AL_2O_3).

Some rock materials from which soil mineral matter is formed are -

calcite - (Ca - C - 0)*
dolomite - (Ca - Mg - C-0)
biotite -(K - Al- Mg - Fe-Sc-0-H)
apatite -(Ca - P - 0 - C -F)

Note the elements in the brackets. Do you see where some of the essential elements are from? Other are from similar sources. eg. Copper and zinc.

Organic matter

This forms the rest of the soil particle. It is derived from decomposed or decayed parts of plants and animals. In its decayed form it is called humus. It contains mineral elements (P, Mg, Fe etc) but is called non-mineral because it contains the elements of organic compounds (C - H - 0) in larger proportions than inorganic matter.

Soil, air and water - These occupy the space between the particles and their proportions in the same soil, will vary at different time. After heavy rains most of the spaces will be filled with water, but as it runs off, the amount of air in the soil will increase. A supply of oxygen in the air is essential for the roots and small soil organisms (eg. bacteria, fungi) to produce their energy.

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* These are not correct formulae but given to show the elements present in these materials.

The water forms a thin film around each particle and tend to stick to the soil particle by a force called <u>capillary attraction.</u> Plants use root pressure as a suction force to overcome this attraction so that water will enter its roots.

The water is not usually pure but contains dissolued mineral salts. These salts contain the essential plant elements. It is in the soil water they dissolve to form the solution which the plant absorbs.

<u>Soil organisms</u>. These are small plants and animals living in the soil. They are <u>Not</u> a part of the soil itself. <u>Types</u> - Worms (eg. earthworm and nematodes) and some insects are the largest, but in smaller numbers compared to the algae, fungi and bacteria. They play a very important part in the breaking down of dead plant and animal parts to humus. They are also sometimes responsible for some terrible diseases of the roots and other parts of the plant. They are relatives of the plant and naturally, there are good relatives and bad relatives.

SOIL STRUCTURE

What is soil structure?

When we talk about the overall soil structure, we do not mean the individual sand and clay particles. Soil structure refers tó the how particles are grouped together to form aggregates. If you take a handful of dry soil and crumble it, each tiny crump or granule is really a group of individual particles or an <u>aggregate</u>.

Good structure vs poor structure.

The overall structure of the soil will depend on the arrangement of the aggregates....

Good structure -

A soil of good structure is one with aggregates well spaced and allowing the free movement of water and air in the spaces. This allows good growth and development of crops.

Poor structure -

A soil of poor structure is one in which the aggregates are lumped together to form clods. Water and air movement in the spaces is not free. The result is that soils of poorer structure do not drain easily and often become waterlogged. Roots cannot move easily between the aggregates, the result is usually poor growth or the plant dies. Soils with a higher proportion of very small particles (clays) are often of poor structure because their aggregates are small and nearer to each other and will easily form clods. This happens when these soils are trampled by animals or machines or when poor practices, such as very regular ploughing of some clay soils, are used in growing vegetables. When dry some of these soils might be powdery and easily eroded by wind. The vegetable grower must always try to maintain a good soil structure for maximum production of his plants.

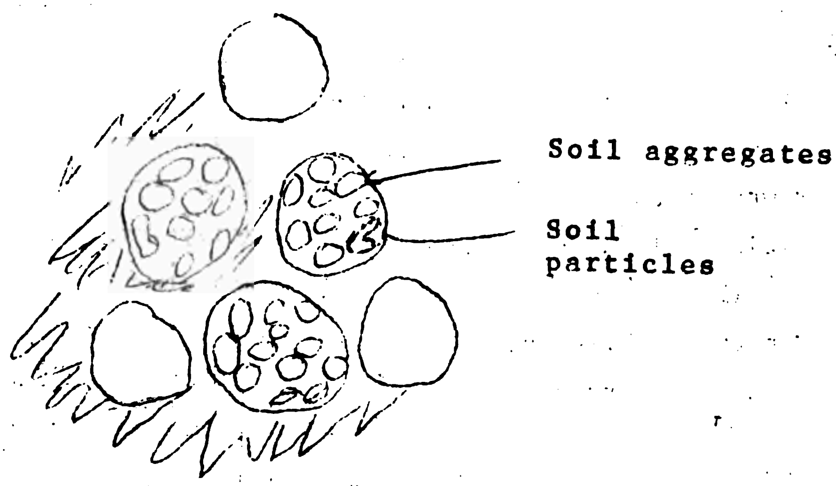
Types of soil particles.

There are three types according to their sizes.

1. Sand - large particles (0.02-2.01mm in diameter). That can be seen with the naked eyes and have a coarse feel in the hands.

2. Clay- very small particles (under 0.002 mm in diameter) and can be seen only under a microscope. They have a powdery feel when dry, and sticky when wet.

3. Silt - intermediate in size between sand and clay particles. (0.02 -0.002 mm) in diameter).



(5:8) (a) Aggregates in Soil structure

Types of inorganic soils

There are 3 basic mineral soil types - viz (1) sands (sandy) (2) clays and (3) silts. Looking on the names one will see that soil types must directly relate to texture.

How are soil types related to texture?

Sandy soils - contain 70% or more sand particles. (It is called sandy soils to avoid confusion with sand which is not soil. It is pure organic material produced from breaking down or weathering of rocks. It needs the organic matter to make it into soil). So that if 10 lbs (4.5 kilo -gms) of sandy soil is dissolved in water and the particles separated over 7 lbs (3 kilo-gms) will be sand particles.

Properties of sandy soils

1. They have a course feel which is due to the large rough particles that make up the bulk of it. They are called light soils.

2. These soils are very loose and roots move through easily, but water also passes through rapidly and makes this soil difficult to grow vegetables.

Clay Soils - contains 40% or more clay particles.

Properties of clay soils

1. They usually have a sticky feel and holds much water and plant nutrients. They are called heavy soils.

2. They become easily water logged.

3. Roots do not move through easily and with their easy water-logging tendency, make vegetable growing difficult, unless certain practices are applied.

Silt soils - contain over 80% percent silt particles. They are not as common as sandy and clay soils and share some of the properties of both types.

Loam soils - These are soils containing a mixture of sand, silt and clays in roughly equal proportions. Most often one type is dominant. If sand is dominant, the soil is a sandy loam, if its clay loam, and if silt its silty loam. Clay loams and sandy loams are most common and better for plant growth.

Properties of loam soils

1. They lack the coarseness and rapid water movement (drainage) of sandy soils. They can hold more water.

2. They lack the stickness of clays and will not become easily water-logged.

3. They allow roots to pass through easily and therefore good for vegetable production.

If the texture of the soil is the proportion of sand, clay and silt particles of which they are composed and the soil type is also determined by the proportion of these particles, we can say that soil type is determined by texture - or different soil type have different textures. This is the link between soil texture and soil type. However, other features like the amount of humus (hence different colour) and its internal drainage helps to determine soil types.

Inorganic vs organic soils

Sands, silts, clays and loams are inorganic or mineral soils. These soils contain from a very small amount of organic matter to as high as 20%. But there are soils containing over 20% and as high as 90% decayed organic matter (humus) and are called non-mineral or organic soils. Although organic soils might be so high in humus, those with over 80% are not usually cultivated as they are often too soft.

Types of organic soils -

There are two main types -

peat soils,
muck soils.

Peat soils are made up largely of slightly decayed organic matter while muck soils are completely or nearly completely decayed. As a result, peat soil might be made up of fibres (material looking like dry coconut husk or coir). Muck soils have fine particles which when dry might be powdery and easily eroded by wind. The humus in them give them a dark or near black colour. It is for this reason that some people make the mistake of calling organic soils humus. Humus is not a soil, but decayed organic matter that is a part of mineral soils and a larger part of non-mineral soils.

Properties of organic soils

The properties of these soils will depend on the amount of organic matter making up the soil and the extent to which it is decayed (ie partly or completely).

1. Structure. - Generally these soils are of good structure, they will allow fairly easy passage of air and water through their spaces, and are easy to cultivate. Because of the porous nature of some of these soils, some have a spongy or rubbery feel.

2. Moisture - These soils can hold a higher quantity of moisture than mineral soils. Dry mineral soils can hold 1/5 to 2/5 their weight of water (i.e 5 lbs (2.3 kilo-gms) dry soil hold 1 or 2 lbs (.5 or .9 kilo-gms water), while dry organic soil will hold 3 to 4 times its weight (i.e. (2.4 kilo-gms),5 lbs dry soil hold 15 to 20 lbs (7-9 kilo-gms) water).

3. Nutrients - Like mineral soils, the amount of any element will vary from one place to another. However, compared to inorganic soils generally, organic soils are usually higher in N, lower in P and K, with secondary and micro-nutrients at about the same levels.

Uses of organic soils

1. Manure- Organic soils being rich in humus can be applied as manure to mineral soils. It will have to be dug up and applied to the soil where it will both enrich and improve the structure of the inorganic medium. The details of how this is done will be dealt with later.

2. Crop production - The good structure and the ability of these soils to absorb and retain a relatively high amount of moisture,in addition to the ease with which non-mineral soils can be worked,make them suitable for producing high outputs of vegetables. There are certain factors that can limit production. Among them are the need to use only light equipment for land preparation, low supply of P and K on these soils and the tendency for nutrients to leach out of the root zone of most crops.

Soil Weight

The weight of a given amount (or volume) of soil is usually expressed in 2 ways, namely, bulk density and Area weight

1. Bulk density is the weight of a unit volume of dry soil. This weight is usually less than particle density, which is the weight of the particles in the soil. Bulk density is the more important one for us in this book since we will use it later to calculate fertilizer needs of a crop on different soils

Example:

10 c.c of soil weighs 13.5 grams.

$$\text{Bulk density} = \frac{\text{weight of soil}}{\text{volume of soil.}} = \frac{13.5}{10} = 1.35 \text{ grams per. c.c.}$$

The bulk density of clay, clay loams and silt loam surface soils is usually

1.0 to 1.8 gms / c.c. Sandy soils are usually 1.2 to 1.8 gms / c.c. To convert grams per. c.c to pounds per. c.c. we multiply by 62.4. This 62.4 is a standard which is the weight of 1 cubic foot of pure water.

2. Area weight is the weight of 1 acre or hectare of dry soil. When this weight is for an acre of soil to a depth of 1 ft, it is on the weight of an acre-foot. Working with bulk density, 1 cubic foot (.03 c. metres) of soil (1' x 1') usually weighs 65 to 110 lbs (30-50 kilo-gms) by converting 1 acre to square feet, we can calculate a rough weight for an acre-foot of this dry soil. This is usually 3 to 4.5 million pounds. For a depth of 6 inches (15 cms), the weight is about 2 million lbs (1 million kilo-gms). This 2 m. lbs. is a standard most often used to express soil weight and is called the acre - furrow weight(or acre - furrow slice).

The soil weight can be used to calculate the amount of each element in an acre-furrow.

Example:

A soil test shown that a given soil type has 0.1% N, 0.05% P and 0.2% K.

$$\text{wt. of N} = \frac{0.1}{100} \times 2,000,000 = 2,000 \text{ lbs}$$

$$\text{wt. of P} = \frac{0.05}{100} \times 2,000,000 = 1,000 \text{ lbs.}$$

$$\text{wt. of K} = \frac{0.2}{100} \times 2,000,000 = 4,000 \text{ lbs.}$$

When the amount of available nutrients in a soil and the nutrient requirements of a crop is known, this can be used as a guide to the kind and amount of fertilizer to apply to that soil .

Physical features of soil. (contd.)

We have so far looked at two important features of soils i.e texture and structure. We will now look at a third one - colour.

Colour of inorganic soils.

Colour of mineral soils is due mainly to the parent material, the structure and amount of humus in the soil. The parent rocks sometimes give a soil type ... a range of colour close to that of the rocks but chemical changes in soil formation (eg. red soils from limestone) cause the parent material to change colours. How light or how dark the colour usually depend on the amount of organic matter present in the soil. The more humus in the soil, the darker will be the colour and it is for this reason why top soils are also usually darker than sub-soils.

Example -red colour soils are usually formed from rocks high in Al (aluminum) and Fe (iron) e.g. red clay loam soils (bauxitic soils). But when this type of soil is rich in organic matter, it has a darker red colour.

Colour of organic soils

Organic soils are generally very dark brown to black in colour. This is due to the fact that all organic soils are high in humus and all humus is from the same parent material i.e. plants and animals.

How is soil colour important?

The colour of the soil by itself is of little importance to either the student, or the farmer of vegetable. Structure and texture by themselves might be important in that we know for example that a soil of poor structure will limit yields. But colour is important only because the colour of the soil indicate other features of the soil that directly affect production.

<u>For example the following colours usually suggest</u> -

1.	Brownish black, dark brown and reddish brown	- high supply of organic matter, good structure and drainage.
2.	Solid red or yellow colour	- fairly rapid drainage, parent material rich in iron, phosphorous tend to be fixed with the iron
3.	Yellow and grey	- poor drainage and low nutrient supply, soil formed from limestone rocks.
4.	Black colours in low lands,	- very poor drainage.
5.	Mottled colours suggest very poor drainage and soil might be waterlogged. (mottling is a mixture of 2 or more colours).	

Soil colours however may tell very little about a soil, for example, some sandy soils are grey in colour although they have very rapid drainage. Similarly, a reddish brown soil may be a clay or clay loam soil with poor drainage.

C. IMPROVING STRUCTURE

The vegetable grower can hardly do anything about the colour or texture of his soil. Luckily for him, he can shape the structure of his soil. Because despite the colour or texture (whether clay or sand, red or brown), by improving his soil structure, he can increase his yield.

Why improve structure?

The most suitable soil for vegetable plant growth is one in which the aggregates are fairly distinct. They must not be clumped together to form clods of soil having small or no spaces between the granules. A soil of poor structure with clumped particles reduces the space for air, water and nutrients and block the growth of the root layers in search for food. It reduces the amount of plant food, the amount of air to produce energy for the roots to grow, and also hinders mechanically, root growth. The result is usually poor growth and poor production of vegetable crops.

Poor structure usually occurs in two forms -

1. When the particles and aggregates are clumped together. This is common in clay soils in which granules are small and near to each other and tend to stick together and form clods.

2. When the aggregates are broken down into the individual particles and the soil becomes powdery. When it is dry it is easily blown away. When wet, it becomes soaked allowing no air to stay between the fine particles. This happen after soil is worked for years without adding organic matter or when poor land preparation methods, e.g. long use of rotovators) are used.

Effects of improved structure.

Improving the structure of the soil is a very important condition which by itself can bring a great increase in vegetable production.

These are some of its effects

1. Allow sandy soils to hold more water;
2. Allow water and air to pass more freely through clay soils. (improve drainage);
3. Makes it easier for the roots to grow in search of plant nutrients.

Note that improving the structure makes more water and air available to the plant. Because the roots can now grow more, it can absorb more nutrients. However, improving the structure of a soil does not actually increase the amount of water or nutrients in the soil. Improving amount of water and nutrients is something separate that the grower will have to do by irrigation and fertilization respectively.

How to improve soil structure

The two most common ways are:-

(1) Improve soil management (2) Adding organic matter to soil.

1. **Improve soil management**

   Ploughing and harrowing must be done when the soil is neither too wet or too dry and with the right type of equipment. Ploughing and harrowing (before or after crop is planted) of wet clayey soils cause aggregates to break down and form clods. Preparing very dry soils can make the soil powdery. Before the soil is ploughed, the aggregates are more compact. By ploughing, clods are usually broken into smaller lumps and by the time the land is harrowed, the aggregates are more separated. If rain falls the sun dries up the soil, breaks it down more, thus further destroying the structure. By loosing the soil water, air and roots can move more freely.

Improved production from these practices are due more to better root development in the loose soil since the actual structure of the soil is hardly changed.

Adding organic matter

How is organic matter added to soil?

Naturally organic matter is added when animals and plants die and their bodies decompose (decay). The soil organisms (micro-organism mainly fungi and bacteria) feed on the organic material as food in their life processes. The material on which they feed decays to form humus. They may use free oxygen in the soil in breaking down the organic matter and energy which they use for their life processes and CO_2 are given off. (This is aerobic respiration). In some cases, they can break down the organic matter without free oxygen present. (This is anaerobic respiration).

How organic manure improves soil

1. Sandy soils -

   Manure added to soil, encourages a rapid multiplication of soil organisms. When this large population dies and their bodies decay, the decayed material forms mucilagenous or gummy substance. This gummy substance helps sand and silt particles to stick together to form aggregates. The result is that it improves the structure and water holding capacity of the soil.

2. Clay soils -

   The gummy substance from dead bacteria and fungi is not as sticky as the clay particles. The result is that it forms areas of less sticky material or lines of weakness between the aggregates. The result is that it improves drainage in clay soils.

Applying manure

The forms of manure are:-

1. Fresh plants and animal parts - Leaves, stem, remains of crops and animal manure (e.g. poultry dropping and cow dung) are added to the soil before they start to decay.

2. Compost - partly or completely decayed organic material added to soil. The fresh material is put in a heap called a compost heap. The heap is turned at certain interyals and is also kept moist by adding water. This is important as it is in this moist medium that bacteria and fungi thrive best. Turning it allows free oxygen to enter the heap so that the organisms can get adequate supply for respiration. They will naturally be in the organic material, but if some humus from a garbage heap is added, it will increase their population, and the process might be speeded up. Compost improves soil more quickly than fresh material.

3. Peat - partly decomposed organic soil that can improve inorganic soil.

4. Sludge - solid remains from toilets that can be dried, treated and added to soil. In town areas, when the toilet is flushed, the excreta is allowed to settle in tanks. Water and certain chemicals are added and the remainder is dried and sold as sludge. (The chemicals take care of the smell). This material like all organic matter, not only improves soil structure, it also supplies valuable plant nutrients. Naturally if we take in the nutrients in food and we pass out the excess in the toilet , it remains in the sludge. Unfortunately for us, most tropical countries allow its sludge to go to waste.

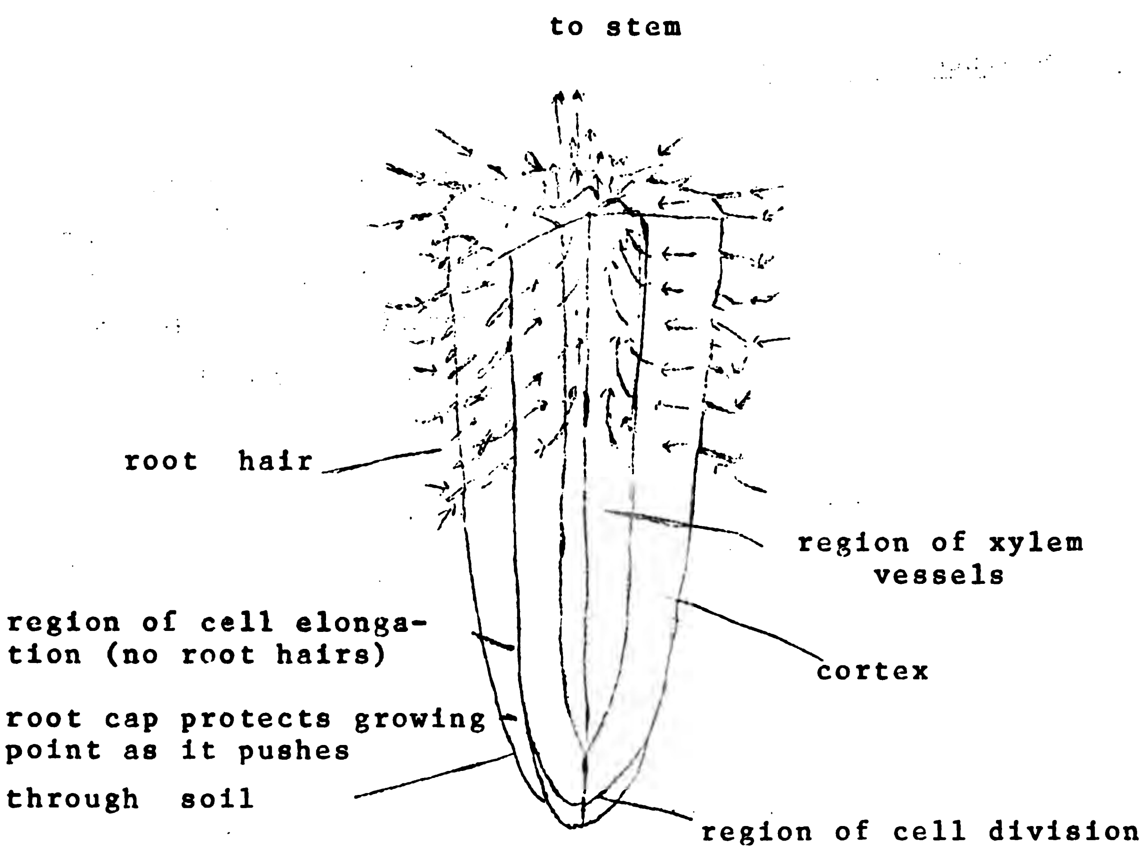
Where to apply organic manure

The organic matter should be left either on the surface of the soil or worked into it depending on the state of the organic matter when applied, (fresh, partly-decayed or completely decayed) and the reason for applying it (improving structure or nutrients).

For improving structure The manure, whether decayed or fresh can be worked into the soil. This should not be done too deeply. The manure can be mixed with the soil during ploughing and harrowing or by using hand tools.
For supplying nutrients, completely decayed material might be worked in the soil, but this is not necessary. However, fresh material or partly decayed should be put on the soil surface. There are 2 reasons for this:-

1. When the organic matter below the soil is put in a very damp atmosphere: The organisms love moisture and in a short time, a large population will be feeding on the matter, The carbohydrates in the organic matter will be quickly used up and the organisms will die of starvation. When they die the nitrogen in their bodies will be rapidly released to the plant. If fertilizer is not added as another source of nutrient, the crop may also starve. But when the manure is put on the surface, it takes a longer time to break down.

2. Another reason is that the organic matter is converted to humus mostly by fungi and bacteria to a lesser extent. Bacteria are found in larger numbers than fungi below the soil surface. By ploughing the organic matter below the surface, the high population of bacteria give off much CO_2 which will further reduce the number of fungi. This is because most fungi use oxygen in their respiration and will not survive in a medium with a high concentration of CO_2. The result is that much CO_2 rather than humus will be formed. This does not improve the soil.



Diagrammatic section of root to show passage of water from the soil

Chapter 6. SOIL WATER AND PLANT NUTRIENTS

A. SOIL WATER

What is the function of soil water?

Water in the soil in some ways has the same basic function as water in our homes. It plays an important part in our food intake and serves the same basic function in the vegetable plant. There are some differences. For example some of our food is taken in as solid material and we drink the water later. This makes the food in such a state that it can be utilised by the body.

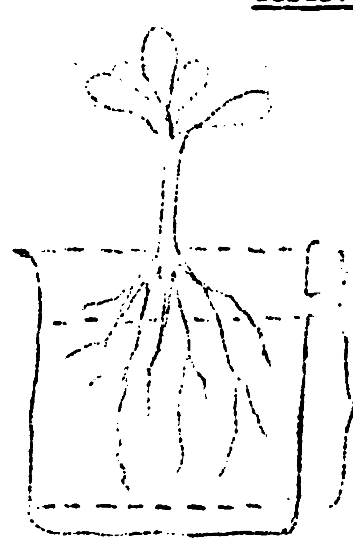
However, when we eat liquid food from sugar-and-water to milk, we do essentially the same thing as the plant. The plant takes in all its foods with water from the soil.

The soil as a water reservoir.

The soil acts as the reservoir for the water that the plant needs.

(6: 1) (a) Root hair in soil

(b) Diagram of soil as reservoir



As all reservoir, water enters at some times, leaves at other times or it enters and leaves at the same time. Naturally there are times when water enters faster than it leaves and at other times, the opposite happens.

Water in - 1. Rainfall - this is the main source of water in the soil.
2. Irrigation - adding water by means other than rainfall.

Water out - 1. Evaporation from soil.
2. Drainage through sub-soil and into parent material. Some runs-off into streams.
3. Absorption by plant. Excess removed through leaves by transpiration.

Saturation point

Take a close look at fig (6: 1)b. It is a diagram to explain how the soil acts as a reservoir for plant water. Immediately after heavy rainfall or irrigation, the reservoir is filled to the brim. In this state, there is little or no air in the soil because all the spaces are filled with water. The soil is saturated and said to be at its saturation point.

Field capacity

The reservoir cannot remain like this, so the excess water is allowed to run off from the outlet at B. This might take a day or two depending on the type of soil. When this takes weeks or months, the soil becomes water-logged. The water rapidly leaves the soil under the force of gravity(natural pull towards the centre of the earth). After the excess water has drained away, the rate of water loss decrease markedly (i.e from rapid to slow). At this point, the soil holds the water against the force of gravity. The soil is now at field capacity.

Available vs unavailable water

Not all the water in the soil can be reached by the roots of the plant. Water in the range of field capacity can be used by the plant i.e. available water.

After plant absorbtion, drainage and evaporation has removed available water, there is still some water left in the soil. This water cannot be absorbed by the plant i.e, unavailable water.

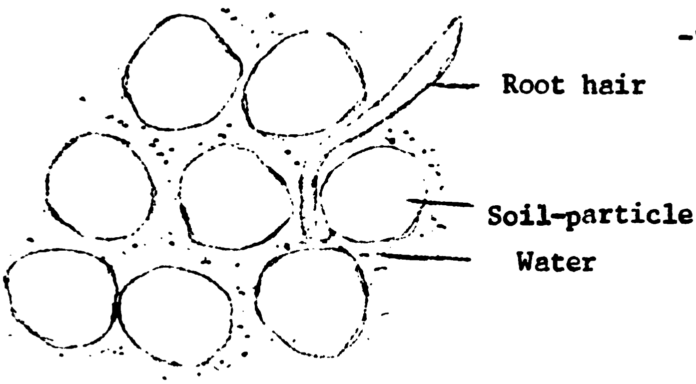
Permanent wilting point.

The plant will start wilting from water level approach C. Because before it actually reached this point, water loss from leaves (transpiration) would be greater than absorbtion by roots. Most of its secondary roots would not be in contact with water.

When water level is at C, the plant would wilt so much that even if it got water then, it would not regain its vigour. It would be permanently wilted hence the soil is said to be at its permanent wilting point.

The true picture of soil water.

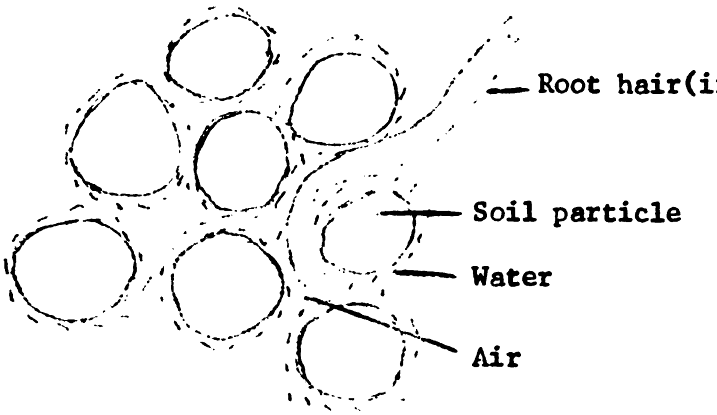
The idea of the soil as a reservoir might be misleading at times. Now that we understand generally the picture in the whole soil, we might look more closely at what actually happens between soil particles, water and root hairs.



Particles	Spaces
Solid	Water

Soil at saturation point

(i) Shows the root hair in saturated soil. The whole root is in water and there is no air around for it to breathe. It is this that causes most roots to rot when kept in saturated soil for long.



Particles	Spaces	
Solid	Water	Air

Soil at field capacity

(ii) Shows the root hair in soil at field capacity. Notice that the root hair is not completely surrounded by water. Air is also in the soil and the root hair is both in contact with air and available water. The root pressure is also stro[illegible] enough to "pull in" the water.

Why permanent wilting?

The water enters the root hairs easily(by osmosis) when soil is at field capacity. As more water leaves the soil, the plant has to apply a greater pressure (root pressure) to absorb the water. This pressure is necessary because the soil particles exert a force (surface tension) that tends to pull the water towards it. At permanent wilting point the pull of the soil particles on water is greater than the pull of the root. The root cannot absorb the water and the plant will be permanently wilted.

B. SOIL TYPES AND WATER MOVEMENT

What is internal drainage?

This refers to the movement of water within the soil i.e. the speed at which water moves through an undisturbed soil. This is not the same as when the word "drainage" is commonly used. In that case, it means the practice used to speed up the internal drainage of a soil.

Water - holding capacity

The water - holding capacity, (or moisture - retention capacity) of a soil, is the amount of water that a soil can retain. This is affected by the internal drainage of a soil and varies from one soil to another. For example, clays hold much water (high water - holding capacity) due to the fact that their particles and spaces are small and water moves so slowly between these particles (slow internal drainage). Sandy soils hold little water because of their large particles and spaces which allow water to pass through easily. They have a low water-holding capacity and a rapid internal drainage.

Internal drainage and water - holding capacity are closely related.

Look at the table below.

(6: 3)

Soil type	Internal drainage		Water - holding capacity
Sands and silts	very rapid	(r_1)	Very low
Sandy loams	rapid	(r)	low
Loam	moderate	(r/s or(m)	moderate
Clay loams	slow	($_s$)	High
Clays	very slow	(s_1	very high

Water logging -

Sometimes the internal drainage of a soil is slow (which also means that its water holding capacity is high) and the soil is located in a flat area. The result is that water cannot run off quickly and the soil is saturated for long periods. It is said to be water-logged. Swampy soils are such examples.

Saline soils

If such soils are near the sea, in addition to being water logged, they are usually salty (saline soils). Some saline soils are not water logged. Vegetables will not grow on these soils and before they can be used, the salt would have to be removed,e.g. flooding the area with fresh water for long periods is one such means. This is a very expensive operation that few tropical growers can afford.

Leaching.

Rapid water loss sometimes cause a washing out or rapid loss of nutrients to the sub-soil and parent material. This is called leaching. It occurs to the largest extent on sandy soils, especially in areas of heavy rainfall. Nitrogen is the element most easily washed out, and it is for this reason that it is often deficient on sandy soils. Leaching can reduce yields considerable. How do you think the vebetable grower could tackle this problem of water-logging and leaching?

C. MAINTAINING SOIL WATER

There are 2 ways we can try to keep enough water in a resorvoir i.e one- supplying water as water leaves this storage, and two - try to reduce the water loss from the resorvoir. It is the same way that the vegetable grower will have to maintain an adequate supply of water in the home for his plants.

How?

Rainfall) Irrigation)	-	adding water
Mulching	-	controlling water loss.

Most tropical growers neither directly or indirectly apply water to their soil. It is done by natural means viz rainfall. This is usually not enough for maximum production of vegetables throughout the year. They have to use water chiefly from rivers to irrigate their field.

Mulching is a means of reducing the water loss from soil. The mulch covers the surface of the soil and protects it from direct effects of the sun. This reduces water loss by evaporation. Grass and other plant material are most widely used by tropical farmers, but wood-shave, plastic and paper can be used on a small scale.

(6: 4)
Top - irrigating vegetables
Below - vegetables under mulch.

D. PLANT NUTRIENTS

Food in the soil.

Nutrients have been mentioned so much that by this, all growers should know what they are and the general purpose they serve in the soil. But let us quickly refresh our memories.

Plant nutrients are the basic raw material that plants absorb and use to manufacture food. There are abour 15 such elements. Two are absorbed from air i.e. carbon (C) oxygen (O) and one from water i.e. hydrogen (H). The other 12 are absorbed from the soil. They are:-

(6: 5)	major elements	(used in larger quantities).		
	Nitrogen (N),	phosphorous (P)	potassium	(K).
	Calcium (Ca)	magnesium (Mg)	sulphur	(S).
	minor elements	(used in smaller quantities)		
	Boron (B)	copper (Cu)	iron	(Fe).
	Manganese (Mn)	molybdenum (Mo),	zinc	(Zn).

The elements in soil are found in mineral salts which will dissolve in water and will be absorbed by the root of the plant.

Available nutrients

It is important that a high amount of each nutrient be in the soil to supply the need of the vegetable plant for maximum production. But very often an adequate supply of one or more elements/is in the soil, but the plant cannot take up as much as it requires. i.e. the elements are not available to the plant.

Available forms of essential elements.

Nitrogen

Nitrogen (N) is available to the plant in two forms. It is available either in the nitrate (NO_3) form or in the ammonium (NH_4) form. In the nitrate form it is easily available to the plant and it is for this reason that the (NH_4) form is usually converted to the (NO_3) form before it is absorbed. This is done by the action of nitrifying bacteria in the soil. It is because nitrogen is so easily available to the plant why it also leaches so easily and becomes deficient to plants.

Adding N

Nitrogen is added to the soil as fertilizers in the following forms -

Nitrates (NO_3)	-	Ammonium nitrate (NH_4 -NO_3) *	appr.	33.0% N
		Potassium nitrate (K-NO_3)	app.	13.0% N
		Sodium nitrate (Na-NO_3) (chile salt-petre)	app	16.0% N
Ammonium (NH_4)	-	Ammonium nitrate (NH_4-NO_3)	app	33.0% N
		Ammonium phosphate (NH_4 - H_2PO_4)	app	11 to 21.0% N
		Ammonium sulphate ($NH_4)_2$-SO_4)	app.	21.0% N
Other forms	-	Urea (CO-($NH_4)_2$	app.	45.0% N.

Some nitrogen is added to the soil by bacteria in roots of legumes and also directly from the atmosphere. (Check nitrogen cycle).

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* Note - The dash (-) used in writing chemical formulae, is intended to make the reader see more clearly, the most important elements or groups of elements in the molecule.

Phosphorous

Phosphorous (P) is available to the plant in the form of an oxide - phosphorous pentoxide (P_2C_5). This element easily reacts with other elements, calcium (Ca), magnesium (Mg) aluminum (Al) and iron (Fe) chiefly to form substances that cannot be dissolved in soil water. Now we know that for the substance to be absorbed by the plant, it must first be dissolved in water to form a solution. It is because of the nature of P to form these substances that will not dissolve (insoluble) in soil water why P is the chief element which might be in soil but largely unavailable to the vegetable plant. Phosphorous fixation takes place on nearly all soils, but to different extents. Example:- Tri - calcium phosphate (Ca_3-PO_4) is a substance containing P but in an unavailable form. When the nutrient is in this form, we say it is "fixed". Red soils, for example, bauxitic soils have high amounts of Al and Fe, and P is usually slowly released in these soils. Adding organic matter with the P fertilizer particularly on these soils increase the availability of P. The living organisms use up some P which they release when they die. But without organic matter, as much as 80% of the P added, might become fixed on some soils .

Adding P.

Phophorous is added as fertilizers in the following forms:-

Super phosphate	(single)	app.	18% P_2O_5
"	(triple)	app.	45% P_2O_5
Ammonium phosphate	(NH_4-H_2PO_4)	app.	48% P_2O_5
* Calcium phosphate	(Ca-PO_4).	app.	35% P_2O_5

* Calcium phosphate fertilizers are made by converting the insoluble tri-calcium phosphate which is mined, to soluble mono- and di- calcium phosphate. Phosphorous does not move much in the soil. For this reason it does not leach as much as say N, but for the same reason it has to be applied nearer to the roots.

<u>Potassium-</u>

Potassium (K) is available to the plant in the form of an oxide, - potash (or potassium oxide - K_2O). In soil it might be found in various forms with the different forms available to plants in varying degrees. However, the greater quantity of potassium in soil (90%) is unavailable.

<u>Adding K.</u>

Potassium is added to the soil as fertilizer in the following forms:-

Potassium chloride (muriate of potash)	(K-Cl)	60% K_2O
Potassium sulphate	(K_2-SO_4)	50% K_2O
potassium nitrite	(K-NO_3)	45% K_2O + 15% N

Sulphate of potash - magnesia (Mg-SO_4-K_2SO_4) 21% K_2O + 53% Mg.

<u>Calcium-</u>

Calcium (Ca) is available in the form of an oxide (Ca O). It is added to soil whether in liming material eg. slake-lime (calcium hydroxide (Ca-$(OH)_2$, marl (calcium carbonate Ca - CO_3) and quicklime (calcium oxide Ca O) Calcium can also be added as fertilizer material gypsum (calcium sulphate Ca SO_4) and calcium phosphate (Ca - PO_4) are examples.

Magnessium -

Magnessium (Mg) is available as an oxide (Mg O). It is added in liming material eg. in dolomite limestone. This liming material contains both magnessium carbonate ($Mg-CO_3$) and calcium carbonate. Mg is added in the fertilizer magnesium sulphate ($Mg - SO_4$).

Sulphur -

Sulphur (S) is available in an oxide (SO_3) form. It might be added to soil as powdered sulphur (S) or in sulphuric acid (H_2-SO_4) or in small quantities with sulphur fertilizers eg. ammonium and calcium sulphates. (Adding minor elements will be dealt with in part 2.)

Nutrient loss

Nutrients are removed from the soil in 3 main ways - viz erosion, leaching and plant absorbtion. These have been dealt with to some extent earlier in the book. However, what we are more interested in now is to find out why nutrients can be in the root zone yet it cannot be absorb by the plant. In short, we want to find out the factors which cause nutrients to be in the soil but unavailable to the vegetable plant.

Why unavailable nutrients?

Soil pH.

When plant elements are in the soil but unavailable to the plant, it is usually because the pH of the soil is not correct for the maximum uptake of the element. The pH of the soil refers to how acid or how alkaline a soil is. Farmers usually call acid soils - sour soils and alkaline soils - sweet soils.

Let us look in more details on pH in order to get a fuller understanding of the matter.

What is pH?

Chemical substances in solution are either acid, neutral or alkaline. For example Hydrochloric acid (HCL), Sulphuric acid (H_2-SO_4) and Carbonic acid (H_2-CO_3) are acid substances. Pure water (H_2O) is a neutral substance. Calcium hydroxide (Ca-$(OH)_2$, potasium hydroxide (K-OH) and ammonium hydroxide (NH_4-OH) are alkaline substances. But there are weak acid and strong acids, as well as weak alkaline and strong alkaline solutions. Hydrochloric acid is strong and carbonic acid is a weaker acid. Ammonium hydroxide is a strong alkaline and potassium hydroxide a weak alkaline substance.

Now because soils are made from different types of rocks and exist under different conditions, naturally they have different substances in solution in (soil water) and different concentration of these substances in different areas. All soils contain both acid and alkaline substances. A soil with a higher concentration of acidic substances (substances that will form acid when dissolved in soil water) will be an acid soil. A soil with a higher concentration of alkaline substances will be an alkaline soil.

Acid soils

The soil gets its acidity (acid) or alkalinity (alkaline) from the soil water. So that a soil which is strongly acid has a high concentration of acid in its soil water. For example, poorly drained soil are usually acid soils. This is because the CO_2 given off by the roots of the plants cannot escape from the soil and will react with the water (H_2O) to form carbbonic acid ($H_2 CO_3$) in solution. .

The same is true of soils rich in sulphur. The sulphur (S) reacts with the water to form sulphuric acid (H_2SO_4) in solution. It is for these reasons thatthe first rule to prevent the soil from becoming acid, is that the vegetable grower should always have adequate drainage. Powdered sulphur may be added to the soil if the grower requires a more acidic soil.

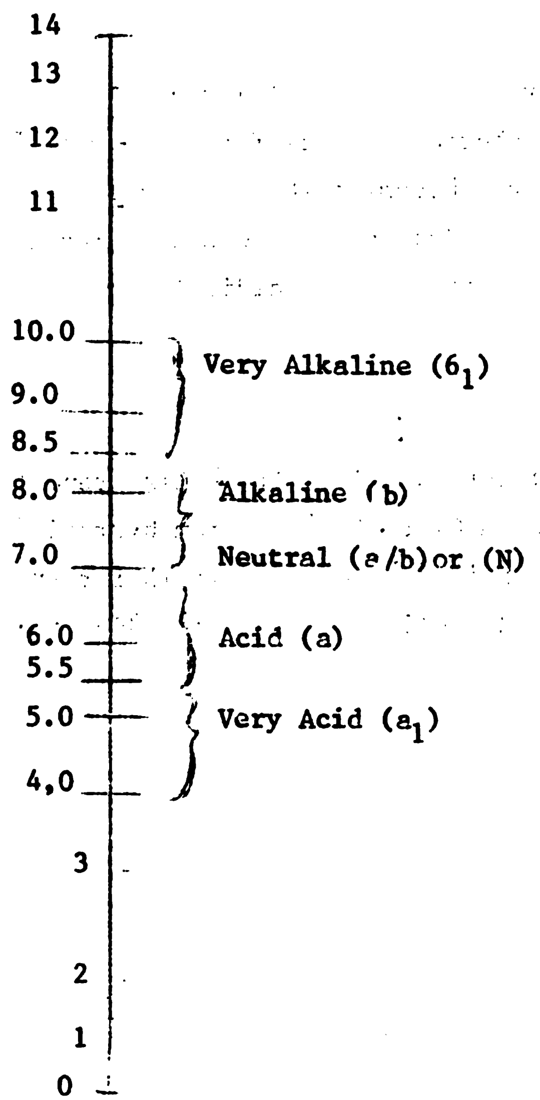
Alkaline soils.

Soils containing much lime-stone ($Ca-CO_3$) for example, marl soils, tend to be alkaline. The $Ca-CO_3$) reacts with HOH (or H_2O) to form calcium hydroxide ($Ca- (OH)_2$ which forms an alkaline solution in soil water. It is for this same reason that slake-lime ($Ca (OH)_2$ or quick-lime ($Ca-CO_3$) is added to make soils more alkaline.

Measurement of pH.

pH scale

The pH scale is a measurement of how acid or how alkaline the soil (or other substances in solution) is.



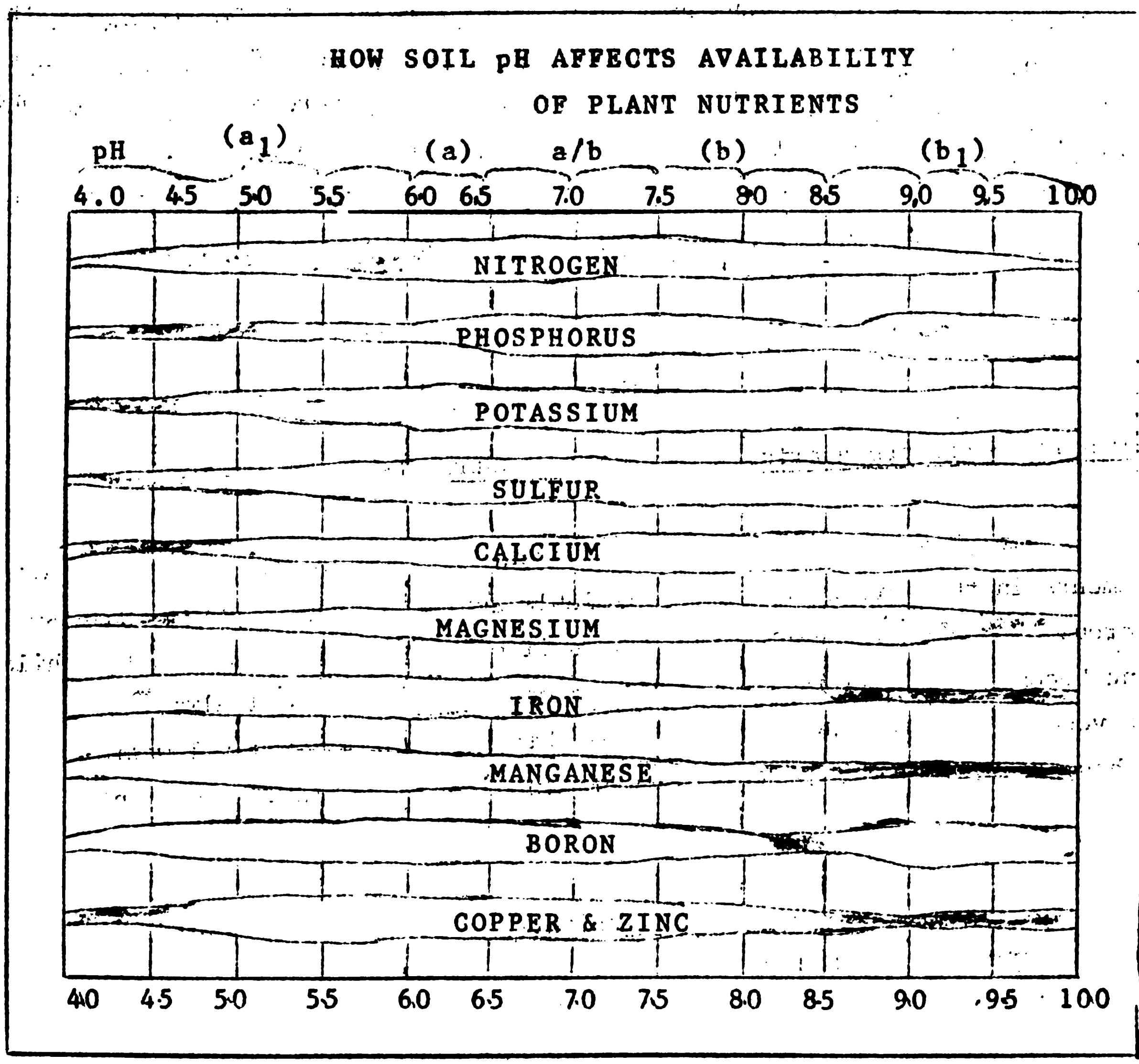
pH scale

(6: 6)

The pH scale runs from 0 to 14. Values from 0 to 7 are acid (a) while values from 7 to 14 are alkaline (b). The value 7 is the neutral point. It is given this value from the pH of pure water which is neither acid or alkaline. Very few soils are neutral, most soils are either acid (a) or alkaline (b).

Note that alkaline substances are also called basic substances (b) but an alkaline substance is a baase that can be dissolved in water. The pH scale above shows pH values and how soil is described according to their pH values. Soils pH below 7 are acid (sour) soils while those with pH above 7 are alkaline (sweet) soils, (All acids have a sour taste. Lime (citrus) contains citric acid).

When we talk about pH value we are talking about a specific number (eg pH of 5.0) while a pH level describes a range of pH values (eg slightly acid is a level and it describes range of pH 6 to 7.



Ref: Cultivator - Esso Publication

How soil pH affects availability of plant nutrients.

For certain pH values each essential element reacts more readily with other elements in the soil to form the insoluble substances. For example, phosphorous becomes less available as the soil becomes more and more acid, while zinc becomes less available as soil becomes more and more alkaline.
The vegetable grower should try to keep his soil at the pH level where the highest possible quantity of total nutrients is available to his plants.

(6: 7) Diagram to show available nutrients at various soil pH level.

What does the diagram say? -

Plant nutrients

Soil pH levels	N	P	K	S	Ca	Mg	Fe	Mn	B	Cu&Zn
Very acid (a_1) (4.0 - 4.9)	L	L	L	L	L	L	H	M	M	M
Very acid (a_1) (5.0 - 5.4)	M	L	M	L	L	L	H	H	H	H
Acid (a) (5.5-6.0)	M	L	M	M	M	M	H	H	H	H
Neutral (a/b) pH. 7	H	H	H	H	H	H	M	M	H	H
Akaline (b) (7.1-8.0)	H	H	H	H	H	H	L	L	M	M
Alkaline (b) (8.1 - (8.5)	M	M	H	H	H	H	L	L	L	L
Very Alkaline (b) (8.6 - 9.0)	M	M	H	H	M	M	L	L	H	L
Very Alkaline (b) (9.0 -10.0)	L	H	H	H	M	M	L	L	H	L

(6:6)

Table to show available nutrients at various soil pH level.

(= low, M = medium, H = high)

The table explained.

The table is intended to explain the diagram. The symbol L = low, M = medium and H = high, describe the available nutrient status at the different pH levels. The reader should not be too worried about the symbols in brackets. Notice that they are the same ones on the pH scale. Some similar ones describe internal drainage. They are included at this stage so that the reader will be familiar with them when they are explained later in part 2.

How to read the table?

To find available nutrient status at one pH level.

1. Put a ruler or a straight edge under the pH level required.
2. Look at the symbols going across under each element. It describes the amount or status of each element at that pH level.

The rows go across (horizontal) while the colums go down (vertical)

Example 1.

In soils with pH to 5.5 (2nd row from top) available N is medium P is low, K is medium etc. To find available nutrient status at various pH levels

1. Put the straight edge to the right of the element required.
2. Look at the symbols going down under the required element.

Example 2.

Available calcium (5th column from left) is low in very acid soil, low in acid and high in alkaline soils.

Look carefully at the table and try to see why vegetables are most productive on soils ranging from slightly acid to neutral (pH 6.0 to 7.0).

Increasing available nutrients

Two main ways of increasing available nutrients are:-

Correcting soil pH.
Adding fertilizers and organic manures.

The vegetable grower will first have to get his soil tested before he knows the amount of each element available and the soil pH.

Correcting soil pH.

Vegetable crops on a whole tend to grow best on soils ranging from moderately to slightly acid. In this pH range, the highest amount of total nutrients seem to be available to them. Now it means that a grower with his soil pH outside this range will have to correct this pH ie. bring it to the required level.

Learn these simple formulae.

1.	Acid + Acid	=	increased acidity
	(a) + (a)	=	↑ (a)
2.	Alkaline + Alkaline	=	increased alkaline
	(b) + (b)	=	↑ (b)
3.	Acid + Alkaline	=	reduced acidity
	(a) + (b)	=	↓ (a)
4.	Alkaline + Acid	=	reduced alkaline
	(b) + (a)	=	↓ (b)

Increasing acidity (a) ↑

From the formula - (1) we can see that to increase acidity of our soil (i.e. make it more acid), we need to add an acid substance. The following can be done:-

1. Adding sulphuric acid (H_2SO_4).
2. Adding powdered sulphur
3. Adding acidic fertilizer eg. urea.

1. Sulphuric acid is not commonly used because it is dear and dangerous.
2. Sulpher can be used but, cost of sulphur and its application is high however, on very sweet soils, this method has to be used.
3. Fertilizer is more often used because in adding the fertilizer, we both increase the acidity and directly increase the amount of available nutrients at the same time. These fertilizers are acid-forming fer-

tilizers i.e. they will react with water in the soil to form acids which will increase the acidity. eg. Sulphate of ammonia $(NH_4)_2SO_4$ reacts with water (H_2O) to form sulphuric acid (H_2SO_4). The ammonium (NH_4) will become available N.

Urea $(CO-(NH_4)_2$ when added to soil will also react with water to form carbonic acid, solutions thus increasing soil acidity. On very alkaline soils, it might take quite some time before the method is effective compared to using sulphur. The methods for increasing acidity is the same as those used for reducing alkalinity. Look at formula (4) and see why?

Reducing acidity ↓(a)

From formula - 3 we can see that to reduce soil acidity we must add an alkaline substance. The following can be done:-

1. Adding lime;
2. Adding fertilizers that will form alkaline substances.

3. Adding lime -

The most common types of liming material are marl $(Ca\ CO_3)$, slake lime $(Ca-(OH)_2$ quick-lime (CaO), dolomitic limestone $(CaCO_3-Mg\ CO_3)$. Quick-lime is most commonly used. Limestone is burnt in a lime-kiln and later dried. When water is added to it, slatke lime is formed. This happens when it is added to the soil. It is the hydroxide $(Ca-(OH)_2$ or $(Mg-(OH)_2$ that react with the acid substances to form more neutral ones thus reducing the soil acidity. If enough of the liming material is added to acid soil, then the soil can be made neutral. The strength of the liming material is measured by its total neutralizing power (T.N.P). The higher the T.N.P. of the liming material is, the stronger is its neutralizing power and the less the vegetable grower has to apply to reduce his soil acidity to the required level.

Marl, dolomite limestone, quicklime and slake-lime have different T.N.P. with marl being the lowest and slaked-lime being the highest.

Fertilizers

Fertilizers are certain materials containing one or more plant elements and when added to soil improves growth and production of plants. There are 2 main types viz - inorganic fertilizers which are made mainly from rocks and organic fertilizers which are made mainly from plant and animal parts.

Some inorganic fertilizers.	Some organic fertilizers
Sulphate of ammonia $(NH_4)_2-SO_4)$	Urea $(CO - (NH_3)_2$
Superphosphate (P_2O_5)	Calcium cyanamide (Ca CN_2)
Muriate of potash (KCL)	

Most fertilizers contain the primary elements singularly or all 3 together. The latter are the N-P-K fertilizers. Other fertilizers contain both secondary and trace elements usually one or two in each fertilizer.

Fertilizers are very important in vegetable growing. Vegetables need a large amount of available nutrients and fertilizer contains a relatively large quantity of nutrients compared to other manures. For example 100 lbs (45 kilo-gms) of muriate of potash might contain 45 lbs (20 kilo-gms) of potash while 1 ton of cow manure (2200 lbs) or 1,000 kilo-gms contain 101 lbs (4.5 kilo-gms) potash.

Organic manures

Organic matter when added to soil in addition to improving soil structure and water-holding capacity also increase directly the amount of available nutrients. The bacteria that decompose the organic matter and convert it to humus, leaves the nutrients in a form that the plant can easily absorb.

Organic manure is more important as a means of improving the soil structure than to supply nutrients. It is better for the vegetable grower to add manure and supplement it with fertilizers for supplying nutrients, than trying to use manures by itself to supply nutrients.

Here are some manures and the approximate amount of primary elements in 1 ton (1,000 kilo-gms) of material.

(6: 9)

Manures	% Moisture	N	P	K	Approx. tot. nutrients
Cow (fresh)	86	11	3	10	24%
Hog.	87	11	6	9	26%
Horse	80	13	5	10	28%
Poultry	73	22	18	10	50%
Sheep	68	20	15	8	43%

Adding fertilizers -

Certain fertilizers when added to soil has the same effect as adding lime. For example nitro-chalk $(Ca-(NO_3)_2$ when added to soil form alkaline substances. They also have the advantage of directly increasing total available nutrients. These fertilizers might be added by themselves or as supplement to liming material.

Note that acid fertilizers should not be added at the same time as lime, because it will tend to neutralize the lime and reduce its T.N.P. These two methods also holds for increasing alkalinity in soil. Check formula - 2.

SOIL TESTS

What do soil tests indicate

1. Soil type
2. Amount of available nutrients in soil.
3. Soil pH.
4. Internal drainage and moisture-holding capacity of the soil.

How accurate the test indicates the soil conditions will depend on the method of soil test used. The two methods commonly used are field and chemical tests. The latter gives quicker and more accurate results.

In Part 2 we will see how the results of soil tests are used in vegetable farming and will also apply some of what we have learnt in Part I. The more practical side of vegetable production.

APPENDIX I

COMMON NAMES	BOTANICAL NAMES
Broad beans	Vicia faba
Lima beans	Phaseolus lunatus
Kidney beans	Phaseolus vulgaris
Soya beans	Glycine max
Beet	Beta vulgaris
Brocolli	Brassica ruvo
Brussels sprout	Brassica oleracea (gemmifera)*
Carrot	Daucus carota
Cabbage	Brassica oleracea (capitata)
Cauliflower	" " (botrytis)
Chinese cabbage	Brassica pekinensis
Celery	Apium graveolens
Chard (Swiss)	Beta vulgaris (cicla)
Corn	Zea mays
Cucumber	Cucumis sativus
Endive	Cichorium endivia
Garden-egg	Solanum melongena
Kale	Brassica oleracea (acephala)
Kohl-rabi	" " (gongylodes)
Leek	Allium porrum
Lettuce	Lactuca sativa
Muskmellon	Cucumis melo
Mustard	Brassica juncea
Okra	Hibiscus esculentus
Onion	Allium cepa
Cow pea	Vigna sinensis
Garden pea	Pisum sativum
Gungo pea	Cajanus cajan
Parsley	Petroselium crispum
Pepper (sweet)	Capsium annum
Potato (non-sweet)	Solanum tuberosum
Potato (sweet)	Ipomoea batatas
Pumpkin	Cucurbita mixta
Rhubarb	Rheum rhaponticum
Radish	Raphanus sativus
Squash	Cucurbita pepo (melopepo)
Spinach	Spinacia oleracea
Tomato	Lycopersicon esculentum
Turnip	Brassica campestris
Watermelon	Citrillus vulgaris

* Names in brackets are varietal names.
Botanical names are sometimes called the Latin names.

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