URGENT PLANT PEST AND DISEASE PROBLEMS IN THE CARIBBEAN

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Proceedings of the First Meeting of
The Society for Plant Protection in the Caribbean
held in
Kingston, Jamaica from November 22–27, 1981

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Edited by
Chelston W.D. Brathwaite and Gene V. Pollard

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URGENT PLANT PEST AND DISEASE PROBLEMS IN THE CARIBBEAN

Proceedings of the First Meeting of
The Society for Plant Protection in the Caribbean
held in
Kingston, Jamaica from November 22–27, 1981
and organised and sponsored by
The Ministry of Agriculture (Jamaica)
The Inter American Institute for
Cooperation on Agriculture (IICA) and
The Society for Plant Protection in the Caribbean (SPPC)

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PREFACE

The Society for Plant Protection in the Caribbean was proposed at a meeting of Heads of Plant Protection in the Caribbean held under the auspices of IICA in Barbados in July, 1980. A draft constitution was accepted at a meeting of Heads of Plant Protection in Latin America and the Caribbean in Mexico in November, 1980. According to the draft constitution the objectives of the Society are:

1. To strengthen inter-governmental and inter-institutional cooperation in plant protection in the Caribbean

2. To establish a forum for the discussion of plant protection issues affecting Caribbean agriculture

3. To act as a forum for the exchange of ideas and information among plant protection personnel of the Caribbean

4. To promote and stimulate research and teaching in plant protection subjects, *viz.* Entomology, Plant Pathology, Weed Science, etc. and to ensure that these are integrated into the discipline of plant protection

5. To stimulate discussion and actions to ensure that the Caribbean environment remains free from contamination by pesticides

6. To carry out all other activities which may be associated with preserving the plant genetic resources of the Caribbean from destruction by pests and diseases as may be defined by the Executive Committee

The Society held its first meeting from November 22-27, 1981 in Kingston, Jamaica. The theme of the meeting was "Urgent plant pests and disease problems in Caribbean Agriculture". The objectives of the meeting were to formally establish the Society for Plant Protection in the Caribbean and to initiate implementation of its objective as they relate to urgent plant pests and disease problems in the Caribbean.

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The meeting was attended by ninety-four (94) participants from Barbados, Dominica, the Dominican Republic, Grenada, Guyana, Haiti, Jamaica, Montserrat, Saint Lucia, Saint Kitts, Suriname, Trinidad and Tobago and the United States of America.

The opening session took place at the New Kingston Hotel and was chaired by Mr. Walter Van Whervin, Interim President of the Society and Principal Research Officer of Plant Protection in the Ministry of Agriculture, Jamaica. Welcome addresses were given by Mr. Van Whervin, Dr. Percy Aitken-Soux, Director of IICA in Jamaica, and the Parliamentary Secretary, Ministry of Agriculture in Jamaica, Mr. Brasco Lee.

In his address, Mr. Lee welcomed the formation of the new Society and noted that such a Society was long needed in the region. He outlined the importance of plant protection and plant quarantine in the agricultural plans of his Government and in support of regional efforts remarked that "it is in our collective self-interest to keep the zone, region and hemisphere free of dangerous pests and disease". Dr. C.W.D. Brathwaite, Regional Plant Protection Specialist, IICA and Interim Executive Secretary, Society for Plant Protection in the Caribbean gave the keynote address on "The Challenges for Plant Protection in the Caribbean in the 1980's and beyond". Dr. Brathwaite reviewed the current status of pest and disease control in the region and identified the constraints to the successful implementation of plant protection programmes. He remarked that removal of these constraints were the challenges for plant protection personnel in the Caribbean in the 1980's and beyond.

There were three technical sessions held during the first three days of the meeting. On the fourth day participants made field visits where they viewed activities relevant to plant protection in Jamaica. On the fifth day members engaged in administrative matters concerning the formation of the Society and this included the adoption of a modified draft constitution and the election of officers for the 1981-1983 term. The meeting ended on Friday, 27th November. This document contains edited versions of the technical presentations made at the meeting.

December, 1982

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ACKNOWLEDGEMENTS

The contribution of the Ministry of Agriculture in Jamaica who agreed to host this meeting at short notice and the dedicated efforts of its staff especially of the Plant Protection Division, is deeply appreciated. In addition, the financial contributions of the following firms or organizations who are either sustaining members of the Society or made financial contributions to the meeting are hereby acknowledged:

NAMES OF FIRMS	COUNTRY
Banana Company of Jamaica	Jamaica
Bayer Caribbean Limited	Barbados
Caribbean Chemicals and Agencies Limited	Trinidad and Tobago
CIBA-Geigy SA	Guatemala
Citrus Growers Association	Jamaica
Cocoa Industry Board	Jamaica
Coconut Industry Board	Jamaica
Coffee Industry Board	Jamaica
Commonwealth Foundation	United Kingdom
Consortium for International Crop Protection (CICP)	U.S.A.
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OPENING

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INAUGURAL ADDRESS

THE ROLE OF A SOCIETY FOR PLANT PROTECTION

by

Mr. Walter Van Whervin

President, Society for Plant Protection in the Caribbean
and Principal Research Officer (Plant Protection)
Ministry of Agriculture, Jamaica

Distinguished guests, ladies and gentlemen; it gives me great pleasure to welcome you all to this our inaugural meeting of the Society for Plant Protection in the Caribbean. It is an extreme pleasure to welcome our delegates from overseas to our beautiful and beloved country. Some of you from overseas have been our friends and colleagues of long-standing. We have often deliberated together on matters of great importance to Plant Protection at several regional and hemispheric meetings. Many of you have been frequent visitors to Jamaica and we hope that you have fond memories of her. It gives me the greatest pleasure to recall our invaluable exchange of ideas and our deliberations on knotty problems of national and regional importance to Plant Protection. This sharing of experience has been most valuable in the development of a collective experience.

I am indeed very mindful of the great honour you have bestowed on me to be Interim President of the Society for Plant Protection in the Caribbean. This honour is perhaps more meant for Jamaica in recognition of her over-all Plant Protection System. For whatever reasons you might have had I thank you most sincerely for this great honour.

Today, I hope, marks an historic occasion - the inauguration of the Society for Plant Protection in the Caribbean. A society of this nature has been a long felt need in the region. Many have dreamed away a life-time hoping for a Society for Entomology in the Caribbean; others a Society for Plant Pathology in the Caribbean or a Society for Nematology in the Caribbean. Now we are on the threshold of forming a more comprehensive and all-embracing Society. It is a dream that is about to materialize. Why has this dream, the aspirations of

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Scientists in the fields of Plant Protection, taken so long to materialize? Was it that the number of Plant Protection Scientists was too small to form a society? Was it parochialism? Why this obsession to form a Society for Plant Protection in the Caribbean? Is there really a need for such a body? Are there National and Regional benefits to be derived from such a Society? I shall give but a few of the many benefits that may be derived from the Society. It will provide:

(i) a forum for discussions, exchange of ideas, deliberations, analysis and evaluation

(ii) a forum for the development of common strategies and contingency plans to contain or eradicate or prevent the introduction of new pests and diseases into the region or even to draw up a programme of collective participation for a national eradication programme in order to minimize the risk of pests or diseases spreading to other countries in the Caribbean

(iii) a think-tank to find solutions to national and regional Plant Protection problems

(iv) a medium for the transfer of technology and increase in knowledge, understanding and awareness

(v) a meeting place where junior scientists are exposed to the research work of mature researchers; in essence it will provide the opportunity for scientists to learn from each other

(vi) it will provide an invaluable forum for cooperation and integration.

Let us now turn our attention to an historical analysis of the Caribbean Region from the point of view of Plant Protection. There are many who appear to be oblivious of the fact that the region has an history in Plant Protection. It is a rich legacy and worthy of academic study and serious review. Those who would look only to the Metropolitan centres for concepts and models would do well to look more closely into their own back yards. It is not now appropriate for me to present an in-depth review but merely to point out a few of the many milestones along which Plant Protection has travelled. The whole Caribbean

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Region has had a very rich, solid and interesting history in the field of biological control. It was particularly dominant in the early 1930's to the mid1960's. There have been conflicts over concepts and models as has been exemplified during the 1930's to the mid 1950's by the controversybetween Harold Box and J.G. Myers on the one hand and R.W.E. Tucker on the other on what was the most suitable biological agent to commercially control the sugar cane moth borer in Barbados. Some other scientists such as the world renowned W.R. Thompson, an eminent scientist in population dynamics, got into the fray. There have been some very notable successes and failures in the field of the biological control of insects in the Caribbean. Perhaps the attempts at the biological control of the sugar cane moth borer, *Diatraca saccharalis* F., and the citrus blackfly, *Aleurocanthus woglumi* Ashby amply typify the hard work, sacrifices, ingenuity, creativity, frustrations and drama of some of our by-gone scientists. The citrus blackfly, indigenous to South Asia, was first discovered on citrus plants in the New World in Jamaica in 1913. Biological control of the citrus blackfly has been noticeably successful in most cases. Commercial control of the citrus blackfly was achieved in Cuba in 1932, less than two years after the introduction of the aphelinid parasite, *Eretmocerus serius* Silv., from Malaya. A similar dramatic experience occured in Jamaica; in 1932 a consignment of 350 adult *Eretmocerus* was received from Cuba. Again within two years (1932-1934) the citrus blackfly was completely under economic control over practically the whole island. However, when this same parasite was introduced into Mexico in 1938, its effect was disappointing except in limited areas of persistent high humidity. It was only after further exploration for other parasites and after intensive distribution of another aphelinid, *Prospaltella opulenta,* that adequate control was achieved in most of the drier areas in Mexico. The subsequent failure of *Eretmocerus* in Jamaica to economically control blackfly led to the introduction of *Prospaltella opulenta*, which within two years effected commercial control. The drama of the attempts to control the sugar cane moth borer, *Diatrea saccharalis*, with the viviparous parasite, *Lixophaga diatraeae*, was even more profound. The parasite was easily and quickly established in St. Kitts within two years, whereas it took a longer time in Antigua but was eventually successfully established. In Barbados however, many attempts were made to permanently establish the parasite. Liberations were made in 1934, 1935, 1949, 1950, 1958 and 1965 yet the parasite failed to permanently establish itself in Barbados. Mr. Tucker, from as early as 1937, had claimed that "The larval parasite, *Lixophaga diatraeae*, is useless in Barbados if left to fend for itself in the field." His detractors, Mr. H.E. Box and Dr. J.G. Myers, had guaranteed the

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permanent establishment of the parasite in Barbados. Mr. Box said in 1927 "Indeed I could guarantee that the Tachnid fly, *Lixophaga diatraeae,* of the Greater Antilles would become a permanent settler in Barbados if brought over in sufficient numbers." The most recent programme (1958-1965) has more than fulfilled Box's criterion because in the years 1961 and 1962, 45,548 and 90,677 gravid females respectively were liberated in the greater part of Barbados. These were the largest number of *Lixophaga* that have been liberated anywhere for a comparable area of sugar cane. These two examples, I hope, convey the idea that biological control is a complex discipline that requires much research and that with our present state of knowledge in that discipline dogmatism is dangerous.

During the 1960's and 1970's there was a general shift in emphasis to chemical control of insect pests and diseases. This shift is due in part, I believe, to a greater predicatability of the end result of chemical treatments. Yet it is true to say that many of us during this period implemented the concept of integrated control.

We are very happy that this Society is coming into being because we are convinced that the concept of regional cooperation and integration is a sound one. There are some things that are regional in scope, particularly in the field of Plant Quarantine. This is particularly so in the more expensive aspects of Plant Quarantine such as post-entry quarantine. We need to develop a common plan or strategy to keep out exotic pests and diseases. In the areas of research we need to exchange notes.

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KEYNOTE ADDRESS

THE CHALLENGES FOR PLANT PROTECTION IN THE CARIBBEAN IN THE 1980'S AND BEYOND

by

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Regional Plant Protection Specialist
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Executive Secretary, Society for Plant Protection in the Caribbean

BACKGROUND

The Caribbean, stretching from Belize in the West to Suriname in the East comprises countries which vary in size, political, racial, social and economic circumstances. Except for Trinidad and Tobago where in 1980 petroleum resources contributed more than 40 per cent of the national output, 64 per cent of Government revenues and 85 per cent of exports, the countries of the region are heavily dependent on agriculture as a source of employment, foreign exchange and food.

The population of this area now estimated to be about 18 million will, like most parts of the world, double by the year 2000. While some research is being carried out on non-conventional sources of food, it does appear that this population will have to be fed from conventional agriculture of which crop production enterprises are major components.

The prospects for producing food for this ever-increasing population are not at all bright. This area imported US$685 million in food from the United States alone in 1980 (Anon, 1981). The Food and Agriculture Organization of the United Nations in a recent document entitled *"Agriculture Towards the Year 2000"* reports that if food and agriculture production continues to expand in developing countries only as fast as it did in the past two decades (about 2.7 per cent per annum), most of the developing countries will face extremely serious

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problems of food supply. The food self-sufficiency as measured in calories, would fall from 92 per cent in 1980 to 80 per cent by the end of the century, leading to a frightening new form of food dependency. Cereal grain imports could grow ten-fold to 14 million tons per year. This could result in an agricultural trade deficit for the developing countries of about US$36,000 million by the year 200. Undernourishment and hunger would be widespread. This report, however, argues that if agricultural output could be increased by one per cent, a major step towards self-sufficiency in food could be achieved. This one per cent increase in agricultural productivity could be achieved by large investments in agriculture and rapid modernization of farming techniques.

If the countries of the Caribbean are to be among those which will achieve the one per cent increase that is needed to avert the bleak picture projected for agriculture in the year 2000, then a major effort must be in removing the constraints to increasing agricultural production in the region. While you may agree that many of these constraints are socio-economic and political, e.g. there is land reform, improvement in infrastructure, marketing, credit, etc., there is much evidence to suggest that improved control of pests and diseases offer one of the quickest and most economical ways of improving the productivity of some crop production enterprises (Brathwaite, 1980).

LOSSES DUE TO PESTS AND DISEASES IN THE CARIBBEAN

In a Seminar/Workshop on *"Pest and Pesticide Management"* held recently in Barbados, one of the major conclusions drawn was the great need for improved control and management of various crop pests and diseases in the region. In fact, if one reviews the various country papers on major pest and disease problems one wonders how it is at all possible to achieve any crop production in the region. In Grenada and Carriacou, for example, 60 species of major pest status were identified; and this is in a cultivated area of approximately18,699 ha (Buckmire and Ogilvie, 1980). In Belize, annual losses in sugar cane production caused by the sugar cane froghopper *(Aeneolamia postica jugata)* have recently been estimated at 100,000-150,000 tons despite heavy pesticide usage (Cawich and Roches, 1980).

In Trinidad and Tobago losses to froghopper *(A. varia saccharina)* at Caroni Ltd. are also very substantial. Recent assessments suggest that 3000 to 4000 tons of sugar may be lost annually and the cost of insecticidal control may amount to US$625,000 per annum (Mahadeo, 1979; T. Copee, pers. comm.).

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Major losses in sugar cane in the region may also be caused by the small moth borer, *Diatraea* spp. especially *D. saccharalis.* The results of a survey of different areas of Trinidad in 1975, suggest that the percentage of bored joints varies from 1.3 per cent to over 20.0 per cent. Sampling in subsequent years showed increased infestation. In fact, it has even been suggested that because of the nature of *Diatraea* damage, sugar loss may be higher than in froghopper-damaged cane (Mahadeo, 1979). This, however, is purely speculative at this time. Similar and even higher damage levels by *Diatraea* are recorded for various other islands in the region; for example, 3.0 to 5.0 per cent bored joints in Guyana (McDonald and London, 1980) and one estimate for St. Vincent of 53.0 to 73.0 per cent (Browne and Lewis, 1980).

In Barbados, where this pest has been effectively controlled with its natural enemies *Lixophaga diatraea* and *Apanteles flavipes*, estimates in 1965 suggested that an economic benefit of US$800,000 per annum accrued to the industry due ot bio-control strategies (CAB, 1976).

If we look at the economic significance of leaf-cutting ants in the new world, estimated losses have been put at US$6 million to US$8 million (Robinson, 1979). In Trinidad and Tobago losses in citrus and cacao have been variously estimated at between US$33,000 and US$250,000 exclusive of yield loss (Cherrett and Simms, 1968; Lewis and Norton, 1973).

We can continue to give numerous examples of pre-harvest losses in various crops and come up with similar data. In a recent consultative meeting held in Trinidad and Tobago, attention had been focussed on post-harvest losses in the region. In Dominica, for example, it is estimated that pests and diseases cause a 50 per cent loss in all produce that are not processed. For the period 1978-1980 for example, such losses were estimated at over US$4 million (Clarendon, 1981). In Guyana losses in stored rice paddy vary between 10.0 to 30.0 per cent (Kennard and Forde, 1981). While there are no firm data for many other countries in the region, they all indicate relatively large estimates of post-harvest losses to the level of 40.0 per cent and more. The works of Fennah, Parasram, Buckmire, Sommeijer and others have all shown that there is a large number of insect pests of food crops in the region.

In the legumes, *Heliothis virescens* (F), *Fundella pellucens* Zeller and *Ancylostomia stercorea* are recognised as major pests which can result in as

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much as a 68 per cent reduction in yield. Bruchids, *Callosobruchus* spp. attack the seeds of most legumes and are major storage pests. In soyabean production the occurrence of species of *Anomis, Hydeleptera, Ceratoma* and *Anticarsia* can result in total loss of the crop and so successful production of this crop in the Caribbean will require effective control of these pests. Pest problems of *Vigna* spp. (including *V. unquiculata* which is widely grown) and on *Phaseolus vulgaris* have also been reported and will require effective control for the successful production of these crops.

Plant diseases also pose a serious threat to successful production of legumes on a large scale in the region. The available data indicate that plant diseases are one of the most limiting factors in the production of grain legumes regionally especially in the case of the common bean, *Phaseolus vulgaris* L. The major disease problems of leguminous crops are anthracnose of bean *(Colletotrichum lindemuthianum), Cercospora* leaf spots of *Vigna (Cercospora canescens* and *C. cruenta)* and peanut (*C. arachidicola* and *C. personata)*, rust on beans *(Uromyces phaseoli* var. *typica)* on peanut *(Puccinia arachidis)* and on pigeon pea *(Uredo cajani).*

In addition to the above, there are a number of root diseases caused by species of *Macrophomina, Rhizoctonia* and *Sclerotium*, bacterial diseases caused by species of *Xanthomonas* and a number of virus disease problems, e.g. cowpea mosaic virus. While soyabean, because of its rather recent introduction to the region, has rather few disease problems, it is important to be aware that there are many severe diseases of soyabean which, if introduced into the Caribbean, could become of considerable economic significance in the production of this crop.

There are a large number of vegetables currently being produced in the region but pests, diseases and weed problems are limiting factors in their successful production. Studies in Barbados have shown that increases in the weight of cabbage heads of as high as 300 per cent can be obtained by controlling *Plutella xylostella* and cabbage white butterfly *Ascia monuste* (L.) with insecticides. In these studies best yields were obtained with a low hazard pyrethroid compound. Other important insect pests of vegetable crops include pin worm *(Keiferia lycopersicella* Busck) on solanaceous crops, a variety of mites, flea beetles, aphids and white flies (Alleyne, 1980).

Important diseases of vegetable crops include bacterial wilt of solanaceous

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crops caused by *Pseudomonas solanacearum*, black rot of cabbage caused by *Xanthomonas campestris*, southern blight caused by *Sclerotium rolfsii* and a large number of other leaf spots, wilts and root disease problems.

One of the most devastating but not well recognised group of pests associated with vegêtable production in the Caribbean are plant parasitic nematodes. Nematodes of the genus *Meloidogyne* (root knot nematodes), are widespread on crops in the region. In addition, reniform nematodes, *Rotylenchulus reniformis* and lesion nematodes, *Pratylenchus* spp. are also common. Studies have also shown that nematode problems can be severe limiting factors in vegetable production in the region.

Citrus and banana are the two most widely grown tropical fruits in Caribbean agriculture. There are a number of important pests of these crops which must be controlled if commercially acceptable yields are to be obtained. These include for banana, Sigatoka leaf spot caused by *Mycosphaerella musicola* Leach, banana borer, *Cosmopolites sordidus* Germ., plant parasitic nematodes, *Radopholus similis* Cobb and root knot nematodes, *Helicotylenchus multicinctus*. In citrus production, the control of virus diseases, foot rot caused by species of *Phytophthora* and plant parasitic nematodes is important.

Mango *(Mangifera indica)*, guava *(Psidium guajava)*, avocado *(Persea americana)*, pawpaw *(Carica papaya)* and pineapple *(Ananas comosus)* are all fruits with considerable potential for production in the Caribbean. Mango is affected by the disease, anthracnose, caused by *Colletotrichum magiferae;* guava is widely attacked by fruit flies, *Anastrepha* spp.; avocado suffers from fruit rot caused by *Colletotrichum gloeosporioides* and from dieback associated with infection by *Phytophthora cinnamoni* and nematodes. Pawpaw is affected by bunchy top to the extent that in some areas it is very difficult to grow the crop successfully. Pineapples are subject to attack by plant parasitic nematodes.

LEVELS OF PESTICIDE USE IN THE CARIBBEAN AND THE NEED FOR INTEGRATED PEST MANAGEMENT STRATEGIES

Apart from the need for improved methods of control, another area of concern with arose at the Pest and Pesticide Seminar/Workshop mentioned above, was not only the growing use but the levels of usage of pesticides in the

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region. In Barbados, for example, the amount of pesticides used in 1979 was approximately 10^6kg – more than 200 per cent over the amount used in 1968 (Alleyne, 1980). Pesticide imports for Trinidad, Barbados, Jamaica and Guyana are given by Pollard (1980). The increasing trend has been substantiated for Trinidad by Barrow (1980). The situation is not much different for various other countries in the region. Pesticide loads vary from 1.6kg per year in Guyana to 2,409kg per year per km^2 in Barbados or on a per capita basis from 0.24kg per year in Dominica to 4.05kg per year in Barbados (Gooding, 1980).

This almost total dependence on chemicals for pest and disease control has been due to both the ready availability and the recorded success of these chemicals in crop protection. There is also a general lack of awareness of alternative control strategies for particular pest situations. And even when such alternative strategies are known and have proven to be successful, they have not been very widely implemented. For example, there have been many successful biocontrol programmes in the region (Alam *et al*, 1971; Bennett, 1971; Alam, 1974) but this form of control is not a system that can be readily adopted by small scale farmers in the region.

While the concept of Integrated Pest Management (IPM) is now recognised in the region as perhaps the ideal strategy of control, doubt as to the ease of implementation of such a strategy by farmers "growing a heterogenous mixture of crops in small or relatively small areas" has been expressed (Gooding, 1980). Even in the large estates, for example Caroni Ltd. in Trinidad and Tobago with approximately 20,000 ha, no firm IPM strategy has yet been implemented.

One of the difficulties with the implementation of any IPM strategy is the correlation of some pest population level with a loss in crop yield. A review of the literature would fail to reveal many studies to determine pest population levels causing economic injury to crops in the region except perhaps for a few studies on sugar cane where, even here, data vary widely. Such knowledge of economic threshold levels is pivotal to any IPM programme.

Hand in hand with the determination of an economic threshold level is the accurate determination of crop loss. There are relatively few accurate data available for crop losses. This again is not an activity in which the small farmer is going to be involved. Crop loss is not static as indicated by Le Clerg (1971) who suggested that "Experiments should be conducted for at least three years at each

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of a number of locations. Such information needs to be updated perhaps every five years. This will be even more so in the future because of rapidly changing cultural practices, the introduction of new plant varieties and agricultural chemicals." In the region at the producer level, it is perhaps only the large estates involved with production of export crops which can generate such data. Specialists in the various regional institutions must also concern themselves with the determination of more accurate estimates of crop loss data.

THE NEED FOR EFFECTIVE PLANT QUARANTINE SERVICES

In addition to indigenous pest and disease problems, the Caribbean region is constantly exposed to the danger of being introduced to many serious plant pests and diseases from countries relatively near. These include the Mediterranean fruit fly in Central and South America and California, the golden nematode from Panama and Peru, Monilia pod rot of cocoa from South America and Panama, and coffee rust from Brazil and Central America. These are merely a few that are established in nearby countries. In addition, pests and diseases that are equally important but established in countries located at a greater distance include: sun blotch virus and seed weevils in avocado; bunchy top and black leaf streak on bananas; many serious virus diseases, black spot, mal secco, and citrus canker of citrus; cadang-cadang of coconut; coffee berry disease as well as some of the little known virus diseases of coffee. The list also includes some of the dangerous cotton pests and diseases such as: boll weevil, spiny bollworm, Texas root rot and many virus diseases; stalk borers and downy mildew of maize; seed weevils, fruit flies and malformation of mango; smuts and various virus and bacterial diseases of potato; nematodes, stalk borers and bacterial diseases of rice; downy mildews, virus and bacterial diseases of sugar cane; and some of the little known virus diseases of sweet potato and yam.

Breeding and selection of several crops are carried on in the Caribbean, e.g. cocoa breeding in Trinidad and Tobago and Suriname; banana breeding in Jamaica; sugar cane breeding in Barbados; and many other crops either by local Ministries of Agriculture or departments of the University of the West Indies. The operation of an efficient plant quarantine system is vital in keeping pests out of the Caribbean as germplasm is introduced.

Traditionally, we have been exporters of agricultural products, e.g. sugar, cocoa, coffee, etc., which, to a large extent, were semi-processed. More and more

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today, we would like to be exporters of fresh fruits and vegetables. For the marketing of such products, it is not only essential that they be of the highest quality, but they must be free of pests and diseases. Efficient plant quarantine systems will be needed to ensure that external markets survive without endangering the agriculture of the importing country, whether that country be regional or extra regional.

THE CHALLENGES FOR PLANT PROTECTION

Against this background of pest and disease problems affecting crops in the region, what then are the challenges for plant protection in the Caribbean in the 1980's and beyond.

In order to define the challenges it is necessary to define the factors which contribute to the low level of pest and disease control in the region. In my humble opinion, these factors are:

a. Lack of an adequate number of well-trained professional staff.

b. Cumbersome administrative structures for the implementation of programmes.

c. The overloading of technical and professional personnel with administrative functions.

d. Lack of institutional and inter-agency coordination.

e. Lack of facilities and equipment and poor maintenance of existing facilities.

f. Lack of stimulation among professionals.

g. Lack of a sufficient number of sub-professional staff in plant protection and plant quarantine.

h. Lack of funds for research.

i. Lack of an effective communication service to bring protection to the farmer.

The challenges which face plant protection in the region in the 1980's and beyond involve tackling these problems to ensure a reduction in the food losses

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from pests and diseases without substantially increasing the cost of the product to the consumer or polluting the environment.

While the solution to some of these problems are outside the scope of the plant protection personnel, in many cases their responsibility lies in convincing the political directorate that the control of pests and diseases is vital for a productive agricultural sector and that increased financial support for research, training and extension in this area is vital. But over and above that responsibility, plant protection personnel must take up the challenge to:

1. Reduce the spread of dangerous pests and diseases both within and outside the region.

2. Educate farmers and producers about pests and diseases and transfer to them the relevant technology for control.

3. Carry out relevant research to find solutions to current and potential pest and disease problems.

4. Decrease the amount of dangerous pesticides while evaluating and implementing alternative strategies of control.

5. Document and disseminate their findings in order to reduce the cases of duplication of efforts in the region.

Recent events within the Caribbean have made the challenges for plant protection in the 1980's and beyond even greater. I speak of:

1. The recent occurrence of the Mediterranean fruitfly in Florida and California.

2. The occurrence of Moko disease of banana in Grenada.

3. The occurrence of coffee berry borer in Jamaica.

4. The occurrence of leaf scald disease of sugar cane in Jamaica.

5. The occurrence of yellow spot disease of sugar cane in Trinidad.

6. The occurrence of blue mold disease of tobacco in Cuba.

7. The occurrence of smut and rust diseases of sugar cane in the region.

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8. The increasing concern about losses due to leaf cutting ants in Trinidad and Tobago, and the high levels of dangerous pesticides with are being recorded in the region.

9. The reported interception of Avocado seed moth and Mango seed weevil from the Caribbean by APHIS interception records is cause for concern. Black Sigatoka is also known to be present in Belize.

Recognising the challenges for plant protection in the entire hemisphere, the Inter-American Institute for Cooperation on Agriculture (IICA) has established a hemispheric plant protection programme. The Society for Plant Protection in the Caribbean has emerged out of the Caribbean section of the programme.

The establishment of a Society is timely for it represents what we hope will be a new era in cooperation in plant protection in the Caribbean. The objectives of the Society encompass the scope of the challenges which plant protection will face in the 1980's and beyond. It is my personal hope that this meeting will mark only the beginning of coordinated efforts to face these challenges as part of our goal to make the Caribbean one of the areas of the world which will avert the bleak picture projected for "Agriculture in the year 2000".

Meetings such as this one serve to remind us that pests and diseases know no ideological, political or national boundaries and so our neighbour's problem yesterday can be our problem tomorrow.

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INVITED PAPERS

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ECONOMIC IMPORTANCE AND PROBLEMS IN THE CONTROL OF THE COFFEE BERRY BORER *HYPOTHENEMUS HAMPEI* FERR. IN JAMAICA

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INTRODUCTION

The coffee berry borer, *Hypothenemus hampei* Ferr. (Coleoptera: Scolytidae) is one major pest of coffee in many parts of the world (Le Pelley, 1968). Where the pest has become established, Coste (1955) reports that at least 25 per cent of the harvestable produce can be lost, although reduction in the exportable product can be as much as 50 per cent. In Java in 1929, losses were estimated at 40 per cent and in Brazil, where the pest was not controlled in 1927, losses were reported at 60-80 per cent (Paz and Sanchez de Leon, 1972).

At present coffee is produced commercially by eight territories in the Caribbean – Cuba, Dominican Republic, Guyana, Haiti, Jamaica, Trinidad and Tobago, Puerto Rico and Surinam. To most of them, it is an important source of foreign exchange.

The appearance of the coffee berry borer in the Caribbean was first reported for Puerto Rico as early as 1944 and Surinam in 1960 (Ticheler, 1963), then for Jamaica in May 1978 (Reid, 1981b). Its present status in Puerto Rico and Surinam is unknown and it is believed absent from the other coffee-producing territories of the Caribbean.

After the initial distribution in Jamaica was established, a national control programme was implemented in November 1978 (Cowden, 1979). This report will review the control programme as designed and implemented in Jamaica, focus on any existing impediments to total success and discuss possible changes which are being considered. Reference will also be made to the estimated crop losses due to the borer in Jamaica and the implications for the rest of the Caribbean.

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The objective is to alert other actual and potential coffee producers of the Caribbean to the danger and by sharing the Jamaican experience, provide an insight into some possible problems related to control of the pest.

STATUS OF PRODUCTION IN THE CARIBBEAN

Data available on the quantity of coffee produced by member states of the Caribbean are restricted to those belonging to the International Coffee Organization (ICO) (Table 1). In Jamaica, Haiti and the Dominican Republic, the export value of the crop ranges from 13-44 per cent of total exports. With steadily increasing world demands for green coffee (Haarer, 1962) the importance of the crop to the Caribbean is also expected to increase.

In Jamaica export of coffee is an important source of foreign exchange, earning an average of US$5.7 million a year for the past three years (Meghoo, 1981, personal communication). On the basis of acreage under cultivation versus revenue earned, it compares very favourably with more popular traditional export crops such as sugar cane and bananas. In addition, it is a labour-intensive system which provides for considerable employment of urban and rural persons during the production, processing and marketing of the crop.

SYSTEM OF COFFEE PRODUCTION IN JAMAICA

More than 70 per cent of the coffee now being produced in Jamaica is *Coffea arabica* var. *Typica* derived from the Brazilian variety. There are however, small amounts of other varieties (caturra, geisha, etc.) which themselves may have undergone hybridization locally. In addition, the coffee produced in the Blue Mountain area of the island is famous for its high quality (Wellmann, 1961). Importer demand has always exceeded supply.

Overall coffee production is on a mixed-cropping system, often including small livestock on farmer holdings averaging 0.25 ha or less; less than 20 per cent is produced as pure stands under limited shade. Recent reports give a total of 10,137 ha coffee being produced by 37,796 farmers. Elevation ranges from 15-1603 metres above sea level and annual rainfall, from 125 to over 700cm (Table 2).

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TABLE 1. PRODUCTION* AND EXPORT OF GREEN COFFEE IN THE CARIBBEAN. 1972/73-1981/82

	Average 1972/73-1976/77	1977/78	1978/79	1979/80	1980/81	Projected 1981/82
Cuba	448[1]	375	325	300	300	300
	...[2]	..	..	..	..	..
Dominican Republic	854[1]	1025	767	889	850	800
	574[2]	755	487	604	560	505
Guyana	14	17	17	20	19	19
	..	..	..	2	..	..
Haiti	554	519	443	664	460	550
	329	304	228	444	235	330
Jamaica	25	23	14	34	27	30
	10	16	5	22	14	16
Trinidad and Tobago	49	41	39	36	33	41
	36	27	24	20	16	24
U.S. Puerto Rico	187	199	159	183	234	217
	..	..	..	..	..	..

*Expressed in thousands of 60kg bags

[1] Total production [2] Exportable production

-- Not available or negligible

Source: Adapted from Foreign Agriculture Circular-Coffee USDA, FAS October, 1981

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TABLE 2. DISTRIBUTION OF COFFEE PRODUCTION IN JAMAICA, W.I., 1981

	Area (ha)*	No. Holdings*	Range of Elevation (m)	Range of Annual Rainfall (cm)
St. Catherine	2238	5478	30-762	125-250
Clarendon	1858	5776	76-867	125-250
St. Ann	1115	5625	229-914	125-250
Manchester	1320	4846	152-914	125-370
Portland	1033	2463	15-610	190-800
St. Mary	607	2388	30-533	125-250
St. Elizabeth	594	3610	152-533	125-250
St. Andrew	440	1510	305-1603	150-700
St. Thomas	356	1920	152-1585	190-700
St. James	174	799	152-686	190-375
Trelawny	340	1974	76-868	190-375
Westmoreland	50	968	152-381	250-375
Hanover	12	439	213-305	250-375
TOTAL	10137	37796		

*Estimates based on Ministry of Agriculture and Coffee Industry Board Regional Reports.

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Service to coffee farmers is provided by the Ministry of Agriculture extension staff and the Coffee Industry Board field staff. Recently, as part of a drive to increase production and productivity, the Coffee Industry Board formed a development company (Coffee Industry Development Company, CIDCO). This Company aims at becoming a primary producer in addition to providing services to farmers cultivating approximately one ha or more of the crop.

Purchase of coffee is done largely by the Coffee Industry Board through cooperatives controlled by the Jamaica Agricultural Society. Processing is the responsibility of the Coffee Industry Board's central factories and a few private ones. The final parchment (green) coffee is sent to the Coffee Industry Board's Central Grading and Finishing Works in Kingston for export, mainly to Japan.

DISTRIBUTION OF *HYPOTHENEMUS HAMPEI* FERR. IN JAMAICA

Between July and December 1978, it was determined that *H. hampei* was distributed primarily in the three central parishes of St. Ann, Clarendon and St. Catherine which account for 40 per cent of the estimated area in coffee. Here levels of fruit damage were as high as 59 per cent (Reid, 1981b). Parishes adjacent to these were affected mainly in the border areas. By mid 1981, the borer had spread into every parish in Jamaica and up to an elevation of 1050m in the Blue Mountains (Rhodes, Young and Brown, personal communication).

NATIONAL COFFEE BORER CONTROL PROGRAMME, 1978

Although detection of the presence of the pest in 1978 occurred when that year's crop was well advanced, attempts were still made by Coffee Industry Board field staff to reduce crop loss by using foliar applications of the chemicals available at the time, *viz.* Pirimiphos methyl (Metasystox), Fenitrothion (Sumithion 50EC) and finally Endosulphan (Thiodan 35EC). A total of 3737 ha on 10,005 holdings were treated.

In November 1978, an organized programme was implemented based largely on those in existence in Guatemala and Brazil (Reid, 1978). Its immediate objective was the control of damage to the 1979/80 crop to acceptable minimum economic levels. In view of the experiences of other countries (Bergamin, 1944; Paz and Sanchez de Leon, 1972; Toledo, 1947 and Ticheler, 1963) eradication would be a long-term consideration.

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The steps proposed (Figure 1) involved three components:

1. An education campaign using all media and directed at the field officers, farmers and general public concerning the possible ravages of this pest and means of detecting its presence.

2. (i) Efficient post-harvest field sanitation to remove all source of food reserve by destroying the berries remaining after harvest.

   (ii) On holdings of .05 ha or more application of Chlordane 60EC to the area under the trees. Chlordane was a temporary substitute for the Thiodan five per cent dust used in Central and North America.

3. (i) Post-bloom manual removal and destruction of damaged berries.

   (ii) A preventative foliar spray programme using the endosulfan formulation THIODAN 35EC at the rate of 0.4 per cent product.

To achieve its stated objective the programme, as designed, relied on:

1. The availability of adequate manpower and resources.

2. Competent, reliable supervision of field activities.

A management structure (Figure 2) gave ultimate responsibility to the Ministry of Agriculture but involved the Coffee Industry Board personnel at every level. The achievements in a parish would be relayed through monthly reports to the national coordinator.

This programme has continued with minor modifications. Two other chemicals have been included in the foliar spray programme, *viz.* Dimethoate 40 (0.5 per cent) and a Copper Fungicide (1-2 per cent product dependent on the formulation). A system of monitoring was instituted by the Ministry of Agriculture in 1980 to evaluate the effectiveness of the programme. Berries collected by sequential sampling of selected holdings were assessed for damage and adult mortality.

PROGRAMME ACHIEVEMENTS

Achievements for 1978 cannot be quantified since monitoring was not done in a similar fashion to succeeding years. Observations indicated very variable levels of pest population control.

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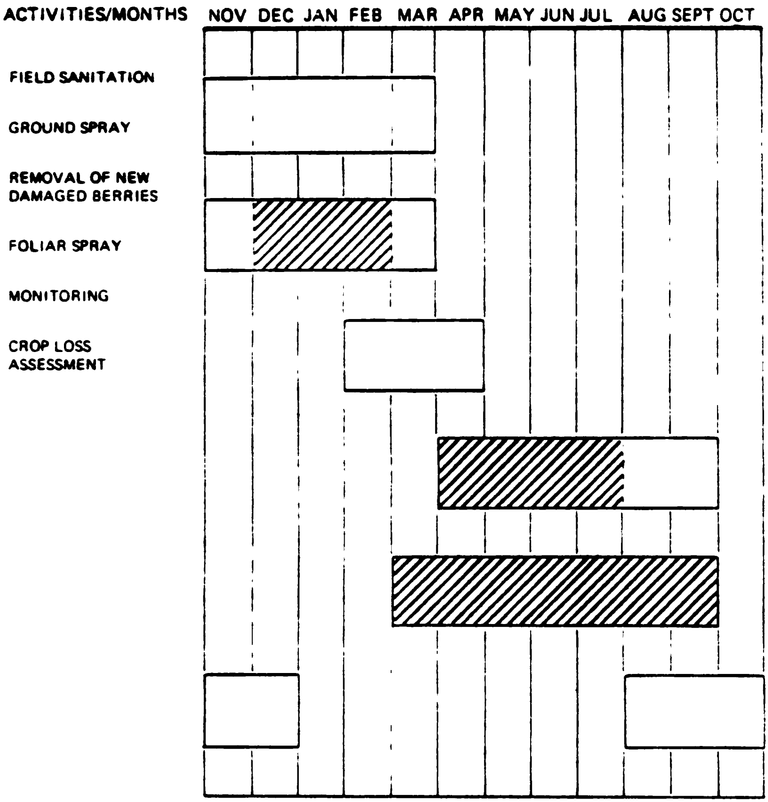

FIG. I. SCHEDULE OF ACTIVITIES FOR CONTROL OF THE COFFEE BERRY BORER, JAMAICA

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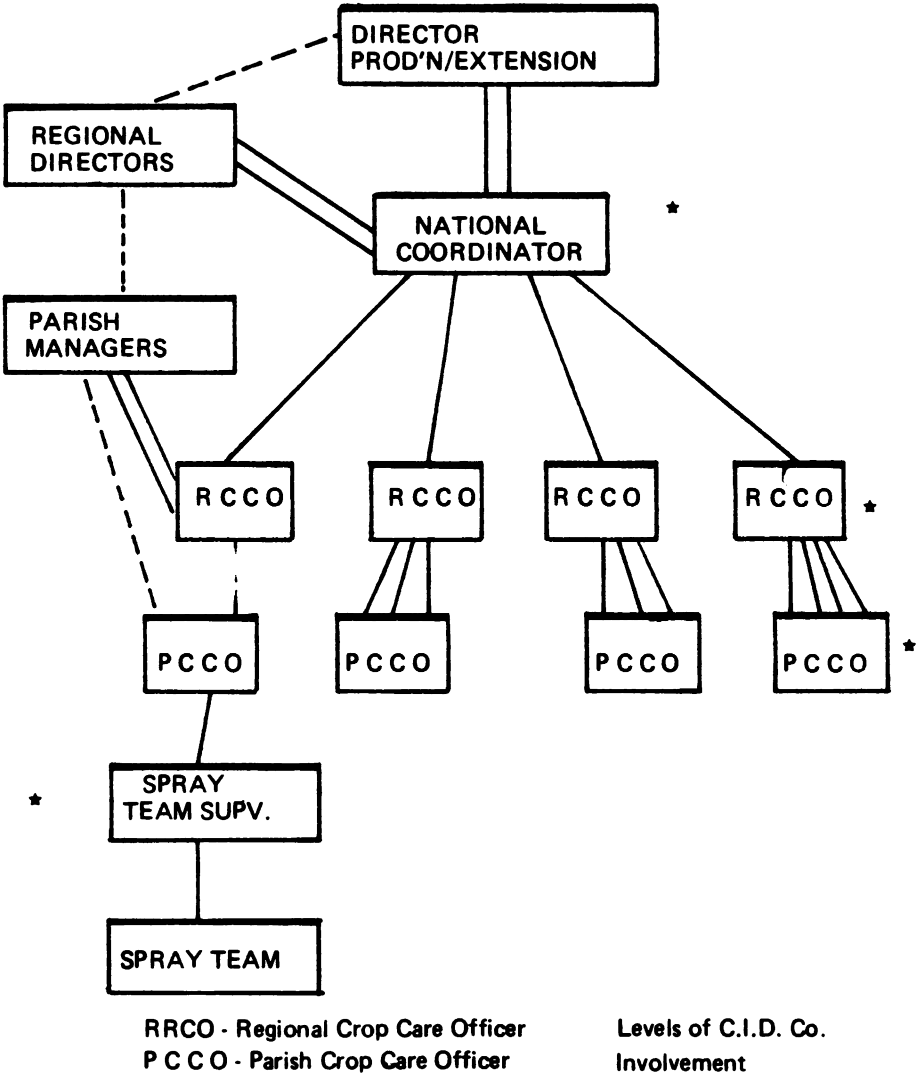

FIGURE 2. ORGANIZATIONAL CHART FOR CONTROL PROGRAMME

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The achievements since inception of the national programme are outlined in Table 3 and Figure 3. It has been impossible to obtain data on the non-chemical achievements of the programme in any year. Reports have been sporadic and inconsistent. The area receiving at least one foliar insecticide application increased from 5842 ha in 1979, to 9241 ha in 1980 and 8693 ha in 1981. Of this area the proportion receiving a second application was 14 per cent in 1979 increasing to 40 per cent in 1981. Increase in area covered was due primarily to an increase in the allocation of resources (equipment, materials and manpower) to service the programme. Financial allocations have reportedly increased from J$0.9m (US$0.5m) in 1979 to J$2.5m (US$1.4m) in 1981.

However, it has not been possible to collect precise information on the cost of the programme. Two major reasons for this are:

1. the fact that some of these costs become absorbed into the normal operating expenses of the Ministry of Agriculture; and

2. because the duration of the programme is governed by the crop year rather than the budgetary one, there has been inconsistency in the system of allocation of expenditure. Clearly there is need for more effective fiscal management.

Estimates of incidence of bean damage in harvested cherry coffee will also give an indication of the success of the programme. In 1979, with the borer present in nine out of 13 parishes, national bean damage was six per cent. This has increased to 10 per cent and 11 per cent in 1980 and 1981 respectively, reflecting the outward movement of the borer, as well as increases in population density in areas where the programme was either not implemented or improperly executed. Although still high, this incidence of bean damage is significantly less than the 29 per cent minimum reported in 1978.

ESTIMATED CROP AND REVENUE LOSS – 1978-1981

Prior to 1978 little attention was paid by the relevant authorities to estimating crop loss due to pests and diseases. Therefore there is no baseline data for comparison prior to the appearance of the borer. Losses to the 1978 crop were estimated to be at least 29 per cent of the production at five factories – equivalent to 160,843kg (US$675,540). With the inception of the programme crop loss fell to six per cent at seven factories – approximately 124,248kg

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TABLE 3. COFFEE BERRY BORER CONTROL PROGRAMME JAMAICA, PARTIAL ACHIEVEMENTS: 1979-1981

	Area (ha) receiving one foliar spray*			Mean % harvested bean damage +		
	1979	1980	1981	1979	1980	1981
St. Ann	805	1115	1056	8	9	10
St. Mary	600	607	538	11	7	8
Portland	257	1033	808	–	–	3
St. Thomas	251	250	356	0	0	N.A.
St. Andrew	298	344	402	3	–	N.A.
St. Catherine	928	1726	2238	5	13	11
Clarendon	1169	1858	1421	6	19	18
Manchester	522	1320	1011	5	13	9
St. Elizabeth	428	594	475	2	6	9
Westmoreland	36	33	49	–	18	12
Hanover	8	8	9	–	–	N.A.
St. James	201	124	174	0	9	9
Trelawny	340	229	156	6	9	11
TOTAL	5842	9241	8693	6	11	10

*Source: Ministry of Agriculture Regional Reports

Note: *H. hampei* distributed in 9 out of 13 parishes in 1979. All 1981 values up to October 31.

\+ CARDI/CIB/CIDCO crop loss assessment programme

N.A. Not yet available

– Not done

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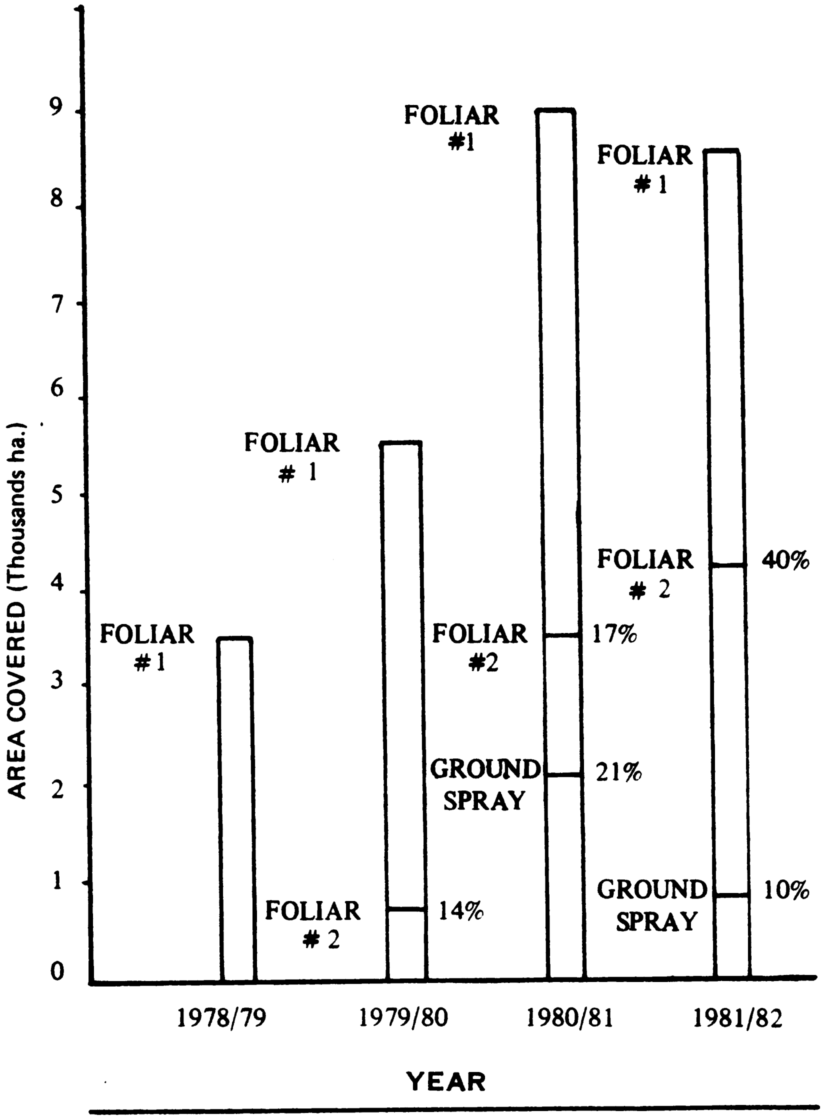

FIG. 3. BREAKDOWN OF ACHIEVEMENTS IN THE DIFFERENT CHEMICAL COMPONENTS OF THE COFFEE BERRY BORER CONTROL PROGRAMME

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(US$583,965) (Table 4). In districts where no control measures were implemented in 1979, bean damage ranged from 30 to 68 per cent. Factory losses for the 1980 and 1981 crops are estimated at present to be at least 11 per cent (Table 5), equivalent to 128,681kg in 1980 and 76,824kg of this year's crop to date (November, 1981).

In an attempt to standardize comparison with 1978 and 1979 figures, the values of Table 5 are derived from actual counts of fruit and bean damage. Further analyses are being done to assess more specifically the different components of loss prior to processing.

PROBLEMS IN THE IMPLEMENTATION OF A CONTROL STRATEGY

Inadequacy of the Quarantine Infrastructure

The length of time for a new pest or disease to be introduced and become established may vary, but is of sufficient duration to allow for detection by a vigilant field staff supported by a well developed quarantine infrastructure. In Jamaica, the quarantine services operate with a minimum of staff and an absence of equipment. Field extension staff have not been trained to detect early symptoms of new pest or disease presence.

Mechanical and Cultural Constraints

Some farmers have resisted the added demands of improved field sanitation out of a basic inability to change (age or lack of resources). At present, the time of stripping is determined by the Coffee Industry Board's central factories and may require an additional cost to the farmer which is not justified by his average returns. In such cases, radical improvement in crop husbandry is an equally critical need.

Introducing the technology for general improvement in coffee culture may cause additional problems. Pruning and removal of heavy shade increase the demands of coffee trees for adequate available nutrients which are often beyond the resources of the farmer. Because of this, the use of litter as a source of mulch and organic manure has been encouraged in Jamaica from the early 1950's. Total removal of litter may theoretically be good pest management for both the borer and *Leucoptera coffeella* (Le Pelley, 1973), but may have serious implications for the short-term survival of the trees and the longer term increase in the incidence of soil erosion.

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TABLE 4. ESTIMATED CROP LOSS DUE TO COFFEE BERRY BORER DAMAGE – JAMAICA, 1978/79-1979/80 (Kg green beans)

Factory	1978/79		1979/80	
	Mean % Bean Damage	Total Production	Mean % Bean Damage	Total Production
Trout Hall	60	228,127	6	669,724
Aenon Town	48	66,955	8	391,351
Clarendon Park	N.A.	N.A.	4	351,687
Bog Walk	32	106,495	4	312,714
Maggotty	5	139,969	2	274,323
Dover	0	13,086	13	50,394
Silver Hill	N.A.	N.A.	0	20,600
MEAN TOTAL	29	554,632	6	2,070,793
ESTIMATED LOSS		160,843		124,248

Source: CIB/CARDI Survey – figures to nearest whole nut.

N.A.: Information not available

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TABLE 5. ESTIMATED CROP LOSS DUE TO COFFEE BERRY BORER DAMAGE – JAMAICA, 1980/81-1981/82 (Kg green beans)

Factory	1980/81 Mean % Bean Damage	1980/81 Total Production	1981/82[a] Mean % Bean Damage	1981/82[a] Total Production
Trout Hall	18	335,041	18	221,730
Aenon Town	12	192,916	10	35,605
Clarendon Park	11	177,800	9	181,312
Bog Walk	12	245,695	10	126,095
Maggotty	11	149,324	9	109,953
Dover	2	32,641	9	23,703
Silver Hill	N.A.	36,409	N.A.	N.A.
MEAN TOTAL	11	1,169,826	11	698,398
ESTIMATED LOSS		128,681		76,824

[a] Source: Survey data up to October 31, 1981 (approximately 50% of crop) CIB/CARDI Survey

N.A.: Information not available

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A final problem which exists is the presence of abondoned farm lots on which coffee trees still exist, as well as the existence of an undetermined number of trees of *C. liberica.* This is a wild variety of coffee which harbours large populations of the pest. Control of this problem is yet to be implemented.

Chemical Control Component

(a) Timing of Application and Crop Phenology

One citical factor in the success of foliar chemical applications using Thiodan 35 EC is the timing of the operation to coincide with the appearance of the susceptible stage of the berry, reportedly two months after fruit set. Local information sugests that the susceptible size is variable and is dependent on many factors. Also, the coffee plant in Jamaica and elsewhere is marked by indeterminate flowering (Fournier, 1980) which may extend from two to five months dependent on the elevation (Figures 4 and 5), thereby causing conflict in the timing of an insecticide application. A possible solution is that of increasing greater synchrony in flower production by applying synthetic hormones. However, this poses the additional problem of management of the harvesting and processing operations which, at present, are structured to cope with a phased input. Timing of the application is also affected by the inaccessibility of some holdings. Attempts to use vehicles on sub-standard roads slow down the rate of achievement and often incur greater costs in down time and maintenance. This problem is further aggravated by the fact that rainfall in many areas is a serious deterrent to pesticide efficency and completion of the foliar spray programme.

(b) Hazards

The regular use of any highly toxic chemical poses its own hazards of acute and chronic poisoning. This risk is increased where applications must be made on steep slopes and in uncomfortable costly protective clothing, the use of which is therefore often resisted (Reid, 1981a).

The impact of the chemical on the environment must also be considered. The performance of different formulations of Endosulfan shows highly significant variations in pest susceptibility response (Rhodes and Mansingh, 1981) which introduces another problem in ensuring an effective control programme. Experimental data (Reid, 1980, unpublished) also show that the use of Thiodan can cause significant increases in damage by *Leucoptera coffeella* Guier. There are other dangers related to environmental contamination. This product is

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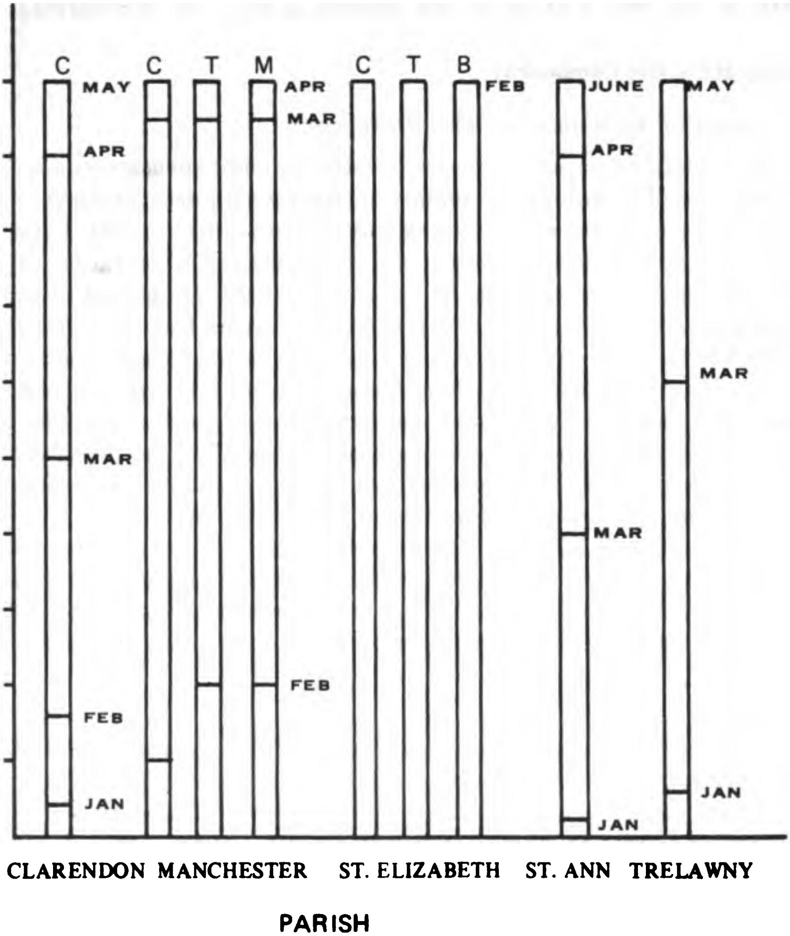

C - Var Caturra
T - Var Typica
M - Var Monex
B - Var Bourbon

FIGURE 4. RATE OF FLOWERING OF COFFEE IN SELECTED AREAS, 1981

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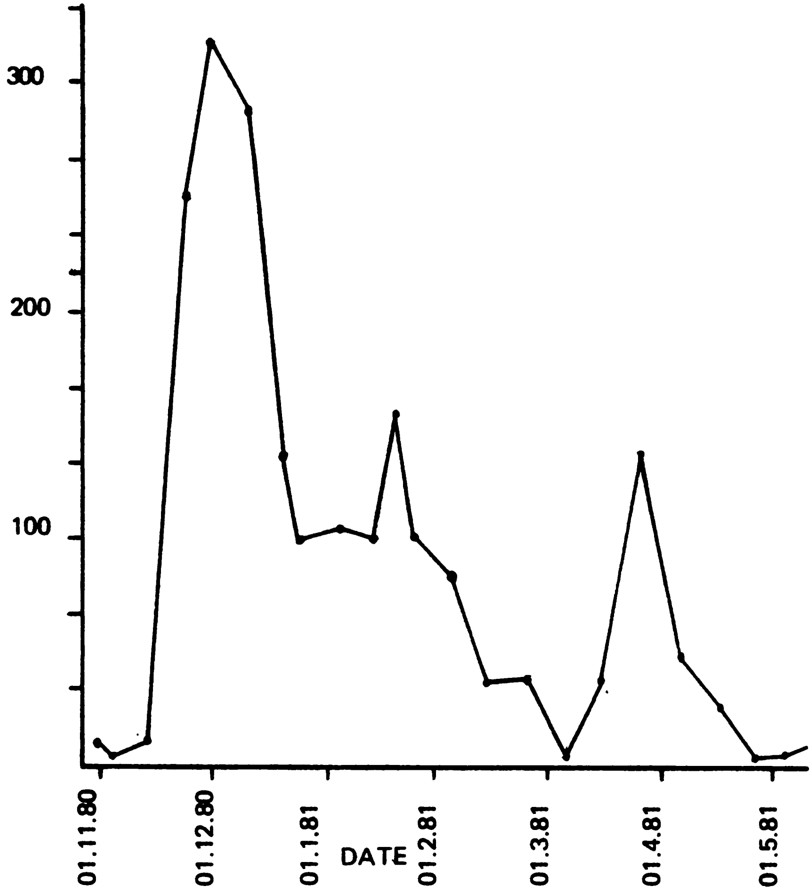

FIGURE 5. RATE OF HARVESTING OF CHERRY COFFEE, WALLENFORD, ST. ANDREW 1980-81

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highly toxic to fish. Serious consideration is needed of the possible contamination of water supplies and food for human consumption and livestock in a mixed cropping system.

MODIFICATIONS TO PROGRAMME – A PEST MANAGEMENT APPROACH

The control programme now operating was designed on a contingency basis in the face of the threat to the industry in 1978. It requires a heavy input of capital expenditure for equipment and transport to be imported and maintained. There is also a tendency to place too much emphasis on the chemical component. Therefore, consideration is now being given to ways of modifying this programme so that it relates more effectively to the Jamaican system of production and its associated constraints.

Modifications, however, cannot be made without information through research. Data being collected since the beginning of 1980 by personnel at the Ministry of Agriculture, University of the West Indies and Caribbean Agricultural Research and Development Institute (CARDI) will provide information on:

(a) the pest biology and epidemiology locally;

(b) pesticide formulation, performance and persistence and effect on other pests;

(c) alternatives to chemical control;

(d) quality control indices.

Attention needs to be given to the development of a fully integrated pest management (IPM) programme for coffee into which would be built agronomic details of crop resuscitation and management compatible with the IPM method.

Management of Resources

The constraints associated with chemical control will require greater emphasis to be placed on the non-chemical components of the programme, as done in other countries. This necessitates a sustained comprehensive training programme for field officers and farmers. It requires the vital information of a detailed farm register compiled by reliable trained staff, which would also be of

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assistance in the event of any other new pest or disease introduction, particularly *Hemilia vastatrix*, causal agent of the coffee leaf rust.

Greater incentives to increase farmer participation in the field sanitation programmes need to be introduced. These can be direct, e.g. marketing quality control indices, or indirect linkage with general resuscitation programmes and resource distribution, i.e. chemicals and fertilizer. However, these methods will only have relevance if there is an expansion in the education programme for both farmer and field officer.

Attention must be directed specifically at providing assistance to farmers in effecting a proper field sanitation programme, e.g.

(i) by modifying slightly the time of purchase and system of collection of "stripped" coffee;

(ii) structuring the system of assistance in providing labour which some method of eventually having the farmer share the cost.

Above all, improvement is needed in overall management of funds, activities and reporting pertaining directly to the programme.

Thought must also be directed at streamlining the coordination of production where all programmes for expansion, production and extension are synchronized into an overall production plan which reduces elements of conflict. Ultimate responsibility should rest with a single agency.

A basic need is for policy directives to be sufficiently strong to ensure coherent implementation of the national control programme at the local level and so save considerable foreign exchange. It may also need the enactment of relevant legislation to ensure that all components of the programme are effective.

Significance to the Caribbean

The ease with which *H. hampei* is disseminated and the close contact by travel between territories of the Caribbean focus on the need for action. For those areas at present free of the pest, it is imperative that increasing farmer education and vigilance of quarantine officers be implemented. Coffee growers and other professionals who travel regularly should also be alerted to this threat which may reduce their own tendency to bring in on their own, interesting new

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varieties. Efforts could also be directed at developing a contingency plan as was done in Mexico and El Salvador for *H. hampei* and in Guatemala for *H. vastatrix.*

There are sufficient similarities in the systems of agricultural production in the Caribbean (Weir, 1980) that should allow this exposure to the Jamaican experience to be of practical benefit to other Caribbean countries.

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A REVIEW OF THE DISTRIBUTION, ECONOMIC IMPORTANCE AND CONTROL OF LEAF-CUTTING ANTS IN THE CARIBBEAN REGION WITH AN ANALYSIS OF CURRENT CONTROL PROGRAMMES

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INTRODUCTION

Leaf-cutting ants (Formicidae; Myrmicinae; Attini) have long been regarded as serious pests in Central and South America including the Caribbean, a fact which has been emphasized at a recent meeting of Heads of Plant Protection in the region. The wide distribution and importance of these pests may perhaps be judged from the fact that there are over 60 local names in the region for each one of the two most important genera, *Atta* and *Acromyrex* (Weber, 1972; Cherrett, 1979; 1980).

This paper sketches a historical background to leaf-cutting ant research in the region, looking particularly at traditional control strategies, various national programmes as implemented over the years and the likely reasons for their success or failure and the likely directions any future work might take.

GENERAL DISTRIBUTION

Leaf-cutting ants are entirely New World in their distribution (Weber, 1972) between latitudes 40^{o}N and 40^{o}S (Fennah, 1950; Weber, 1960). The two major species are *Atta cephalotes* (L.) and *Acromyrmex octospinosus* (Reich), the former being considered the common and most conspicuous *Atta* of north-western South America, Central America (Weber, 1946; Hodgson, 1955) and Mexico (Weber, 1966; 1969). Other species of *Atta* may also occupy these areas but are usually found in well defined or specific localities although the ranges of the different species fluctuate with changes in climate and other factors (Weber, 1969).

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Geographically, *Acromyrmex* has a wider distribution than *Atta*, being found throughout the American tropics from Arizona in the U.S.A. to Argentina (Weber, 1967). *A. octospinosus* is found in the Guianas, Trinidad and Venezuela, whilst *A. octospinosus echina* has been found in Mexico, Rio Frio in Columbia and at Guyaquil in Ecuador (Weber, 1941). In the Caribbean *Atta* or *Acromyrmex* are found on only seven of the islands (Cherrett, 1968a).

Besides differences in their geographic distribution, *Atta cephalotes* and *Acromyrmex octospinosus* may also show differences in local distribution patterns and habitat preferences. In fact the local distribution reflects the geographic distribution. *A. octospinosus* is found in Trinidad for example in sites as the Pitch Lake in South Trinidad to the Five Islands off the north-western tip of the island (Weber, 1945), for this species is more widespread in Trinidad than *A. cephalotes.* The latter is mainly a forest species and naturally is absent from mangrove swamp and probably from open savannah with too sparse vegetation (Weber, 1937; Cherrett, 1968a); *Acromyrmex octospinosus* is restricted more to urban and cultivated areas (Cherrett, 1968a; Lewis, 1975). While reasons for this difference in local distribution are unclear, it has been suggested that habitat preference and selection by newly fertilised queens and the ability of *A. octospinosus* to tolerate dryer microclimates are important (Cherrett, 1968a).

Neither of these species is reported to be found above 550m in Trinidad in the Northern Range (Weber, 1945).* Weber (1937) had suggested that for *A. cephalotes* altitude-limiting factors were probably dripping vegetation and continuously saturated soil although it was possible that these ants could be found at higher altitudes under more suitable conditions. In fact, *A. cephalotes isthmicola* was found on the open slopes of the Cordillera Central of Colombia at Medillin (1969m) and Rio Porce (990m to 1068m) (Weber, 1941).

ECONOMIC IMPORTANCE

Atta and *Acromyrmex* are generally recognised as serious pests in the New World tropical and neo-tropical regions. In fact, in some countries they are considered to be among the most important pest groups (Table 1) (Cherrett and

* D.J. Stradling (pers. comm.) has indicated that a colony of *A. cephalotes* was seen above 915 m on Mt. El Tucuche in the Nothern Range.

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TABLE 1. **IMPORTANCE OF LEAF-CUTTING ANTS AS PESTS (Cherrett and Peregrine, 1976)**

Where there is more than one estimate from a country, the number of estimates and the highest appear in paranthesis.

Country (in order of most northerly part)	Agriculture	Forestry	Range Management
United States of America	****	**(**) (2)	No data
Mexico	***	No data	No data
British Honduras	****	***	**
Honduras	****	***	- - - -
Nicaragua	***	****	- - - -
Columbia	***(*) (2)	** (2)	**(*) (2)
Venezuela	***(**) (4)	**(*) (4)	**(***) (4)
Trinidad and Tobago	****	****	- - - -
Panama	*(****) (2)	*	- - - -
Guyana	****	No data	**
Surinam	*****	*****	No data
French Guiana	*****	*****	- - - -
Brazil	*****	*****	****
Ecuador	***	No data	No data
Peru	****	***	***
Bolivia	***	**	*
Paraguay	***** (2)	** (2)	**(**) (2)
Argentina	****	*****	****
Uruguay	*****	*****	*****

*****	Major importance, one of the worst five insect pests in the country
****	Considerable importance, one of the worst twenty insect pests
***	Moderately important pests causing sporadic economic damage
**	Minor pests, infrequently producing significant damage
*	Unimportant, only recorded on one or two occasions as doing any damage
- - - -	Not known as pests

No data were obtained for Carriacou, Costa Rica, Cuba, Curacao, El Salvador, Guadeloupe or Guatemala.

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Simms, 1968; Cherrett and Peregine, 1976). The latter authors report the results of a survey conducted in the Caribbean and Latin America. Among the 27 countries surveyed, 47 agricultural and horticultural crops, 15 forest species and 13 range plants were reported to be attacked. These included major cash crops like cotton, maize, citrus and cacao as well as subsistence crops like plantains, rice and sweet potatoes. It has been claimed that the carrying capacity of pasture in one state in Brazil was reduced by 800,000 head of cattle because of the leaf-cutting activity of *Atta capiguara* (Gonclaves) (Amante, 1967). Another study in Guyana indicated that *Acromyrmex landolti* (For.) could probably cut about four percent of available grass each day in established pastures of *Paspalum notatum* (Cherrett, Pollard and Turner, 1974). Despite the fact that this figure of a four percent loss was estimated from 'very scanty and probably atypical' data it does indicate the potential severity of the problem particularly where nests of *Acromyrmex landolti* have been recorded at dnesities of more than 62 times the mean density per hectare recorded in the above study (Labrador, Martinez and Mora, 1972).

In one study in Trinidad (Lewis, 1975) it was estimated that if allowed to attain a maximum potential nest density of 153 nests/ha *Acromyrmex octospinosus* could remove 20 to 25 percent of the total leaf area in the first year of a crop of newly established cacao. This was equivalent to a tree mortality of 6 to 17 percent resulting from defoliation. At this same density in established cacao 48,000 flowers could be cut per hectare per day! In citrus orchards at a maximum potential nest density of 36/ha, 20 to 25 three-year old trees could be defoliated each year.

In addition to the data quoted above there have been various estimates of the value of losses resulting from these pests. Cherrett and Simms (1968) quote earlier references in 1923 of estimated annual losses of US$1,000 million in tropical America and US$10 million in Brazil. These same authors estimate that annual losses in citrus and cacao in Trinidad and Tobago amount to US$250,000 exclusive of any yield loss while Lewis and Norton (1973) put such losses at US$33,300. In Paraguay annual losses amount to US$6.3 to US$7.9 million (Robinson, 1979).

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TRADITIONAL CONTROL STRATEGIES FOR ATTINE PESTS – PRE 1960's

The control of leaf-cutting ants has had a similar history wherever attempts have been made. Prior to the early 1960's such strategies had involved either attempts at actual eradication of individual nests or measures aimed at protecting the plant.

In Trinidad for example, eradication measures included the use of various cyclodiene insecticides applied in or around individual nest sights as dusts, emulsions or wettable powders. Various fumigants, e.g. 'Cyanogas' or 'Cymag' were also used directly in nest holes where hydrocyanic gas was produced inside the nest. 'Calypso' (carbon bisulphide) was also extensively used. When fumigants were used the nest holes were frequently blocked and the gas ignited. In this regard mixtures of gasolene and kerosene were also used for 'blowing the nest' as the practice was known.

Actual plant protection measures included either the use of physical barriers, e.g. anti-formicas of some kind or sticky bands around the base of a plant or various chemical repellent compounds. These measures have been described in some detail by Fennah (1950).

In Guyana there was also the early use of carbon bisulphide up to the 1930's which was eventually replaced by cyclodiene compounds. In Brazil around this same time various fumigants comprising gases and toxic smokes were commonly used. A variety of arsenicals, cyanide compounds and sulphur compounds (chiefly carbon bisulphide) were all in use (Mariconi, 1970).

Apart from the use of these various chemicals there has been very little record of other control techniques for attine pests. Various predators have been reported of the protein-laden queens during nuptial flights. Mariconi (1970) lists a number of these as well as parasitoids attacking foraging ants. While these are of dubious importance as regards their biocontrol activity this author is of the firm opinion that the principal cause of the influx of *Atta capiguara* into Sao Paulo in Brazil was due to the decline of bird predator populations resulting from hunting and the destruction of natural habitats.

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CURRENT CONTROL STRATEGIES FOR LEAF-CUTTING ANTS – POST 1960's

Control of leaf-cutting ants prior to 1960 was a difficult, slow and costly procedure apart from the fact that success was not guaranteed particularly when treating large nests which could measure up to 400m in diameter above ground. One small nest of *Atta cephalotes* studied had an above ground area of $35m^2$ with 115 active holes (Pollard, 1973). It would be extremely difficult to effectively control even such a small nest in the traditional fashion.

In the early 1960's the use of poisoned baits was first suggested for leaf-cutting ant control. Such a strategy was employed at the time for control of the imported fire ant, *Solenopsis* spp., in the United States. Essentially a poisoned bait consists of an attractive matrix of some kind which has been 'spiked' with a stomach poison. The ant is attracted to the bait matrix which is carried back to the nest. Incorporation into the fungus garden leads to the poisoning of all individuals subsequently feeding, even non-foraging individuals. This is a sound strategy which has been shown to be both technically and economically feasible wherever it has been attempted. It has consequently formed the basis of all control schemes in practically every country where attine ants are regarded as pests.However, there may be occasion for special formulations of bait if effective control is to be achieved.

The two main components of a bait are the toxicant and the actual bait matrix or carrier. These two components are analysed below.

The Toxicant

Traditionally, organochlorine insecticides (*viz.* aldrin, chlordane, heptachlor and mirex) have been very effectively used in bait formulations. However, this group of insecticides has fallen into great disrepute over the past few years; nearly all organochlorine insecticides have now been banned or placed under restricted use in the developed countries. In the United States, for example, mirex is now banned while aldrin falls into the latter category of use-restriction. This has necessitated a search for alternative non-persistent insecticides. Laboratory and field investigations in the United Kingdom and in this region resulted in the identification of a number of non-organochlorines with great potential (Etheridge and Phillips, 1976; Phillips, Etheridge and Scott, 1976; Phillips, Etheridge and Martin, 1979). However, many of these chemicals did not meet

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the criteria suggested as being essential for bait formulation (Cherrett *et al*, 1973; Etheridge and Phillips, 1976). Essentially any candidate insecticide should be slow-acting over a 10 fold to 100 fold range, non-repellent and of sufficient stability and persistence (1-4 weeks) under field conditions.

Only one commercially available insecticide at the time best met these criteria, the organo-phosphate Dioxathion; in fact it proved to be just as effective as mirex. Other insecticides were also very effective, e.g. Permethrin (NRDC 143), Pirimiphos and Bendiocarb, but their rapid mode of action was an unsuitable characteristic for a poisoned bait. The ant must find and carry the bait back to the nest to allow spread of the poison throughout the colony before being killed. The above insecticides killed foraging ants outside the nest. Further investigation (Phillips, Etheridge and Martin, 1979) indicated that microencapsulation would allow for a slow or controlled release of these rapid-action insecticides. This is an extremely significant development; with the right formulation a whole new series of insecticides are now available for use in leaf-cutting ant control where they were previously unsuitable.

The Matrix

Just as important as the toxicant in any bait formulation is the carrier of the toxicant or the matrix. In the same manner that any candidate toxicant must meet certain criteria so too must the matrix. It must be of uniform particle size (especially important for aerial application); it must weather well without breaking down; it should not be subject to fungal attack (Etheridge and Phillips, 1976). 'Mirex 450', the mainstay of leaf-cutting ant control programmes throughout the region over years, does not meet the latter two criteria.

Ground citrus meal extruded in pellet form, has been widely used as a matrix. In fact, a citrus matrix is so very effective since it contains both arrestant and attractant substances (Cherrett and Seaforth, 1970). However, its effectiveness depends on the particular formulation. 'Mirex 450' is ineffective in wet weather since the ground citrus matrix simply disintegrates – the pellets lose their integrity. Untreated citrus particles of 'MIRICLE BAIT' are also of limited use since they become mouldy under wet, humid conditions both in the field after application and even at times in storage.

Apart from citrus, other material has been suggested for use as matrices once they are non-repellent to the ant, e.g. soya waste or ground cacao pods or

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ground corn cobs (Etheridge and Phillips, 1976). Dried grass has been used as a matrix for the formulation of baits for grass-foraging species in South America (Robinson, 1979). In fact, as a general principle, any agricultural or industrial waste or by-product should be utilised as the matrix in any indigenous programme of bait formulation and manufacture. This would significantly lower the cost of production.

The problems associated with the use of most current bait matrices are those of fungal attack and deterioration under adverse weather conditions. These problems may be overcome in one of two ways. Various compounds may be incorporated into the formulation. A water-proofing agent may be incorporated into a wet season formulation to inhibit deterioration. For example, methyltrichlorosilane (a silicone compound) has been used in this fashion in bait preparation in Trinidad (Lewis and Phillips, 1973). Proprionic acid has been used as an antifungal agent in bait preparation (Etheridge and Phillips, 1976; Phillips, Etheridge and Scott, 1976; Phillips, Etheridge and Martin, 1979; Robinson, 1979).

An alternative strategy in overcoming these problems is the use of different kinds of matrices not subject to deterioration and fungal attack. Various compounds have been investigated. Etheridge and Phillips (1976) have reported that '. . . vermiculite, expanded polystyrene, urea-formaldehyde polymers, pumice, fuller's earth, wood products and gelatin products' have all been tested usually in combination with an attractant and arrestant. The matrix which most closely approximated citrus pulp in activity was vermiculite with sorbed orange juice as the arrestant. This was successfully tested under field conditons in Brazil (Phillips, Etheridge and Scott, 1976).

However, it would still appear to be a more feasible option within the region to continue the formulation of baits using whatever agricultural waste is available together with water-proofing and antifungal agents.

RECENT LEAF-CUTTING ANT CONTROL SCHEMES IN THE REGION

In the English-speaking Caribbean region there have been two recent attempts at nation-wide schemes for the control of leaf-cutting ants. These have occurred in Trinidad and Tobago and in Guyana and have both been joint efforts of the local Ministries of Agriculture and various international aid agencies.

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Case History I. Trinidad and Tobago

A recent survey of the literature has revealed a long history of research activity on leaf-cutting ants in Trinidad and Tobago. There is reference to a paper by C. Brent published in 1886. More recently there have been 26 papers or theses published for the period 1937-1980, inclusive of one each published in 1937 and 1945. The remaining 24 others have all be published since 1950 – an average of nearly one per year (Pollard, 1981). While much of this work has been focussed on aspects of the basic biology and ecology of *Atta cephalotes* and *Acromyrmex octospinosus* there have also been major studies reported on the control of these pests.

There have been much effort in evaluating different matrices and toxicants to obtain the most effective formulation although emphasis has generally been on the production of cheap indigenous matrix which could stand up to wet conditions. Much of this early work in Trinidad has been due principally to Dr. J.M. Cherrett of the University College of North Wales who rekindled interest in Trinidad on leaf-cutting ant research when he spent 1966-1968 as a Research Fellow at the St. Augustine Campus, U.W.I. Cherrett and his research students showed the potential of a local formulation using citrus pulp as the matrix for use in both the wet and dry seasons (Cherrett, 1969; Cherrett and Simms, 1968; Cherrett and Merrett, 1969; Otubu, 1966).

These studies later formed the basis for a long-term project (1970-1973) funded by the British Government's Ministry for Overseas Development on the technical and commercial feasibility of developing a local bait. This project was extremely successful. A formulation (sold as MIRACLE BAIT) was developed which was much cheaper than the imported mirex and which could even be aerially applied (Lewis, 1972; 1973; Lewis and Norton, 1973; Lewis and Phillips, 1973).

This scheme however, was handed over to the Ministry of Agriculture in 1972/1973 who, for a time, took over the actual manufacture of the bait. The Ministry, however, discontinued bait manufacture after two years or so and in turn passed it on in 1975 to the Co-operative Citrus Growers' Association, local manufacturers of canned citrus juices. The reasoning for this decision has not been revealed. Maybe it was felt that under established factory conditions a better, more standardized bait formulation could be made. In fact, earlier

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samples of bait manufactured by the Ministry were going mouldy resulting in some complaints from farmers that it was losing its effectiveness as well. No production data were available from the Ministry. One estimate from the Citrus Growers' Association* indicated that batches of 900kg (20 bags of pulp of 45kg each) were manufactured as required and this was principally as a service to members of the Association. However, the manufacture of toxic bait and a food industry were incompatible to house in one compound. This, combined with the unprofitability of the exercise led to the association itself ceasing the production of bait in 1977. The Ministry of Agriculture is now once again hoping to resume manufacture. At present therefore, there is no bait being locally manufactured and mirex, which was once restricted from entry, is again being imported.

Case History II. Guyana

In Guyana there has been a similarly long history of control schemes for leaf-cutting or 'acoushi' ants as outlined above (Traditional Control Strategies for Attine Pests - Pre 1960's) with the same shortcomings of the various strategies.

Since 1967 when 'Mirex 450' was first used there have been at least four leaf-cutting ant control programmes (Munroe, 1981).

1. 1967-1969 – under the United Nations Freedom from Hunger Campaign.
2. 1969-1970 – United States Agency for International Development (USAID).
3. 1973-1978 – primarily the Ministry of Agriculture, Guyana.
4. 1979 – Food and Agriculture Organization (FAO) Technical Co-operation Programme.

The first two of these programmes consisted essentially of financial assistance to purchase bait or the provision of the bait itself – some 16,000kg for the period 1967-1970.

*Mr. A. Borde, pers. comm. (Co-operative Citrus Growers' Association).

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However, the use of mirex was beginning to be questioned (in fact a National Academy of Sciences report in the U.S.A. (1978) later indicated that the use of mirex against the imported fire ant was 'dangerous and unpredictable' from an environmental point of view). Difficulty in obtaining supplies of this pesticide led to the development of a locally manufactured bait, the third programme mentioned above, by the Ministry of Agriculture in Guyana. Essentially this consisted of a wheat midling and flour matrix with aldrin as the toxicant. The matrix and the toxicant were hand mixed to give an insecticidal dough which was passed through a meat grinder to produce cords which were set in the sun to dry (Rai and Munroe, 1977; Munroe, 1981). This bait, sold under the name of "ATTA", initially proved to be quite effective especially against the smaller *Acromyrmex* colonies. Mean annual production was just over 2700kg for the period 1975-1978.

However, negative reports on the effectiveness of "ATTA" began to be received and it was suggested by Munroe (1981) that a loss in effectiveness may have been due to both the improper mixing of the matrix and toxicant as well as a degradation of the latter when the bait was dried in the sun. Both of these factors were inherent in the very simple manufacturing process.

The fourth programme was then initiated with the assistance of the FAO. Guyana provided a new building which would house new machinery – a mixing machine and a pelleting machine mainly – provided by the FAO together with various technical expertise to work with Guyanese nationals. This plant became operational in May 1981.

An Analysis of the Programmes Described

Research in Trinidad and Tobago had indicated that it was technically and economically feasible to control leaf-cutting ants using a formulation based on a by-product of a local agro-industry. However, the development and implementation of this research has not appeared to have had the same success. Reasons for this have not been documented but is likely due to a combination of factors. There appeared to be insufficient supervisory control when the bait was manufactured by the Ministry and this in turn may have resulted in haphazard quality control. The conditions under which the bait was being manufactured may have also contributed to this. The manufacturing operations were done in what appeared to be a general junk/store-room. Both the raw citrus

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pulp and the prepared bait were stored on the concrete floor. Damp rising from the floor may have accounted for fungal attack of the bait.

The period also saw the beginning of the decline of citrus and cacao in Trinidad, two of the major crops attacked by leaf-cutting ants. While this decline is probably due to various socio-economic factors, the fact of such a decline in these two major crops would have considerably reduced the demand for the bait; hence there was not the pressure from the large number of citrus and cacao farmers on the Ministry to maintain, far less increase, bait production.

At present there is once again a relatively great demand for bait. In the absence of a local bait, mirex is once again being imported – over 50,000kg per year. This retails at approximately TT$15.00 (US$6.00) per kg as compared to the 1974 cost of TT$1.20 (US$0.50) per kg local bait.

In Guyana there is a somewhat different situation where over the past 15 years or so there have been serious attempts not only to control these pests but to develop a local manufacture of the necessary bait. The data presented in Figure 1 indicate the success so far in achieving the latter goal.

However, this was neither an easy nor a one-shot programme. The failure of previous programmes has appeared to be due to a lack of the necessary local finance to sustain the programmes once aid-funds ceased. Robinson (1979) reported a similar situation in Paraguay where for the period 1961-1977 four separate leaf-cutting ant programmes were initiated by both national and international agencies; they all failed apparently for the lack of sustained financing.

In Trinidad it has been difficult to pinpoint precisely the reason(s) for the apparent failure of its programme. There did not seem to be a lack of technical information, expertise or finance.

FUTURE DIRECTIONS

The restriction or banning of the use of all the traditionally used organochlorine insecticides in bait formulation in the developed countries could have led to serious consequences for attine control in the Caribbean and Latin American regions had not some of these countries themselves begun bait manufacture. Brazil now supplies a large part of the region with mirex. However, there

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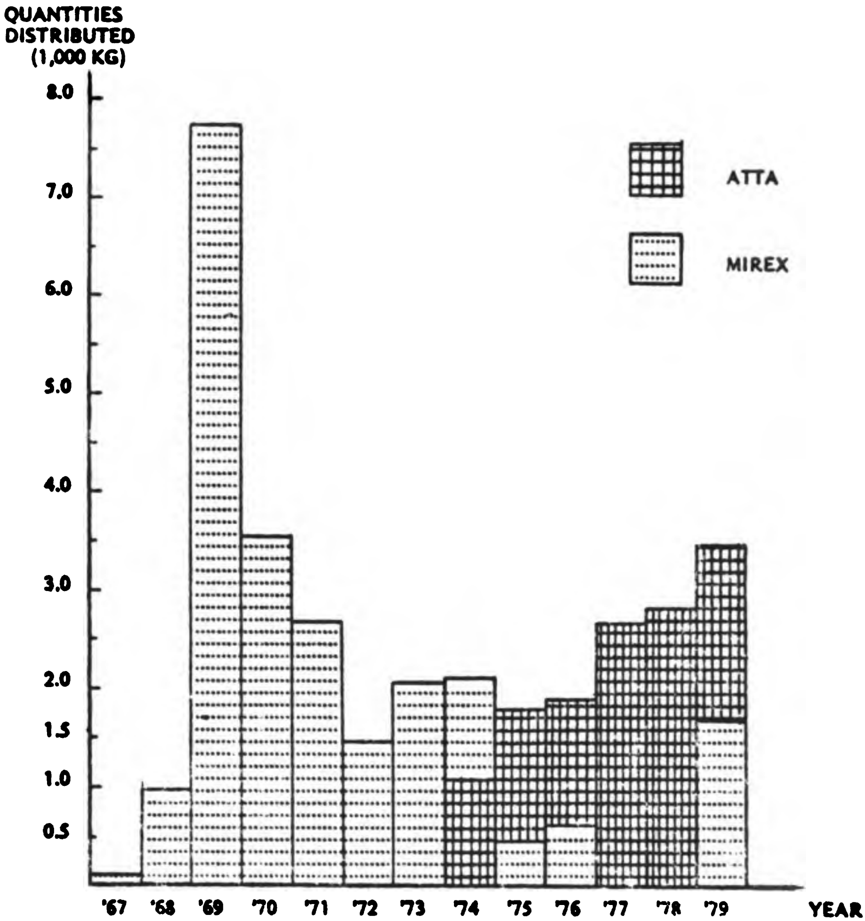

Figure 1. The quantities of 'ATTA' and 'MIREX' distributed in Guyana for the period 1967 - 1979 (Munroe, 1981)

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is no guarantee that these new supplier countries (or, for that matter, the importing countries) may not themselves eventually restrict the manufacture and use of mirex or any of the other compounds.

It is therefore necessary to either develop new chemicals for attine control or new and more environmentally safe formulations of existing compounds. The latter development has been discussed above (Current Control Strategies for Leaf-cutting Ants – Post 1960's). The market potential for the new chemicals has not escaped the chemical companies some of whom have already had new compounds awarded experimental use permits or even conditional registration by the Environmental Protection Agency (EPA) in the United States.

One such chemical has been developed by the American Cyanamid Company marketed as "AMDRO" and which, perhaps, has shown the greatest potential. It was awarded conditional registration and an approved label by the EPA in August 1980 and was the first insecticide which could be applied as a bait formulation aerially or from the ground for imported fire ant control since the suspension of mirex. Like all the other bait toxicants "AMDRO" is a slow-acting stomach poison; however, it breaks down rapidly in sunlight (a half-life of 24 hours) and is insoluble in water. It belongs to an entirely new class of compounds (amidinohydrazones) being neither organochlorine, organophosphate nor carbamate. Although developed specifically for imported fire ant control in the U.S.A. as mirex was, this too should show excellent effect against attine pests.

Another group of compounds which have been tested for effectiveness against leaf-cutting ants are insect growth regulators or morphogenetic agents. These compounds disrupt the development of an insect which may lead to death. They may also act directly on adults. Little, Jutsum and Cherrett (1977) discussed the results of bioassays of these compounds on leaf-cutting ants. While *in vitro* tests against individual ants indicated the potential of these compounds, e.g. Altozar, a juvenile hormone analogue, caused abnormal pupal development and high adult mortality, introduction of these chemicals into living colonies of *Atta* spp. proved to be virtually ineffective. It was suggested that the highly metabolic fungus detoxified any of the test chemical before it could affect the brood which are usually located well within the fungus garden. The fungus was therefore acting as a 'biochemical shield' for the brood. More recently though, Stauffer Chemical Company of the U.S.A. has developed a new growth regulating compound and is currently testing this for activity against attines.

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Another new compound belonging to the oxadiazoles group and coded 32,861 RP is reported to give excellent control against *Atta* spp. in Brazil; in its efficacy was reported to be '. . . comparable to that of mirex' (Ambrosi *et al*, 1979).

Apart from the use of all the various compounds mentioned above whether mirex, aldrin or the latest experimental compounds, there is perhaps one other strategy which could have great potential for attine control. This is the use of resistant plant varieties. Field observation has indicated that the ants do show a certain degree of selectivity in their foraging (Cherrett, 1968b) and that such selectivity is likely due to the presence of naturally occurring deterrent chemicals in the non-selected plants (Stradling, 1978).

At present research in this area is being actively pursued at the St. Augustine Campus, U.W.I. Results of preliminary experiments suggest that certain fractions of extracted sap of selected plants are deterrent to ant foraging.

With the receipt of a research grant from the Organisation of American States, it is expected that more definite results of this work will be forthcoming. Should the presence of phytodeterrent chemicals be definitely established in non-selected plants then this should certainly suggest some exciting possibilities for attine control.

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THE STATUS OF SUGAR CANE SMUT AND RUST DISEASES AND THEIR CONTROL IN THE CARIBBEAN

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INTRODUCTION

The sugar industries of the Caribbean region account for a very important segment of the countries' export earnings, in some cases overwhelmingly the largest. Often too, sugar provides the major source of employment. Its significance to the national well-being of the region is therefore quite profound. The region's impact on world sugar markets is also appreciable as it accounts for one-fifth of total production and one-third of all the sugar traded (Table 1). Any factor which adversely affects production of sugar in the region can therefore be expected to be accompanied by urgent concern nationally and internationally.

The advent in the Caribbean of sugar cane smut and rust diseases during the last six years posed added threats to the viability of the sugar industries, already reeling under the effects of depressed prices and high production costs. The region was generally unprepared for the diseases, and it turned out unfortunately, that large percentages of the land area in many of the sugar industries were planted to susceptible varieties. Those countries which were fortunate to have longer lead time before being infected were, of course, somewhat better prepared, benefiting from the experience and help of others.

SMUT DISEASE IN THE CARIBBEAN

Culmincolous smut disease of sugar cane is caused by the fungus, *Ustilago scitaminea* Sydow, which was first observed in Natal, South Africa in 1877 (as *U. sacchari)* (Luthra, Sattar and Sandhu, 1940). Since then it has been reported from most of the sugar industries in South-East Asia and all of Africa. It was first reported in the Western Hemisphere from Argentina in 1940 and subsequently, from Brazil, Paraguay and Bolivia.

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TABLE 1. SUGAR PRODUCTION AND EXPORT ESTIMATES FOR 1980 FOR CARIBBEAN TERRITORIES (1000 metric tonnes)

Country	Production	Available for Export
Barbados	125	110
Belize	108	101
Colombia	1,169	292
Costa Rica	220	85
Cuba	7,200	6,630
Dominican Republic	1,350	1,160
Florida	1,080	–
Guatemala	450	223
Guyana	340	305
Haiti	67	16
Honduras	220	98
Jamaica	265	140
Louisiana	650	–
Mexico	3,147	–
Nicaragua	214	106
Panama	255	186
Puerto Rico	175	32
St. Kitts	36	33
Trinidad	145	94
Venezuela	395	–

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Smut was first positively identified in the Caribbean region on the variety, HJ5741 in Guyana in December 1974, where it is thought to have arrived via high altitude wind currents from West Africa. Smut has now been observed in all of the countries of the region as shown in Table 2. Also shown are the varieties first infected with HJ5741, B49119, 169-14, NCo310 and B42231 predominating.

The progress of smut disease in the different countries of the region has been varied, depending mainly on the initial acreage under susceptible varieties and the state of preparedness including the availability of acceptable replacement resistant varieties.

Status of Smut Control in Various Countries

The total eradication of smut is most unlikely. In the first place the removal of susceptible varieties from cultivation is dependent on:

- the order of yield loss of these varieties,
- the availability of commercially acceptable resistant replacement varieties, and
- the need to protect high yielding moderately resistant varieties from excessive background spore loads.

In the second place, complete immunity to smut is rare. It should also be noted that some African, Asian and South American industries have lived with the disease for decades. In a country where smut has been widespread, the disease will survive on rogue stools, alternate hosts and odd stalks of varieties which are not immune. There is also reinfection from wind transported spores. In this paper therefore, complete control and elimination of susceptible varieties will imply the reduction of susceptible varieties to less than 0.5 per cent of cane area.

Table 3 gives a summary of the progress in controlling smut in individual territories. Of the 22, eight are in a position to achieve complete control before the end of 1983. These are the five countries that first identified the disease – Guyana, Martinique, Trinidad, Jamaica and Guadeloupe – and Cuba, Barbados and Puerto Rico which had relatively small percentages of their area in susceptibles when smut arrived. Louisiana, Costa Rica, Panama and Belize, having about the highest initial percentage of susceptible varieties, are most unlikely to replace them before 1987. Honduras, Mexico, Colombia, Dominican Republic,

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TABLE 2. CHRONOLOGY OF SMUT DISEASE IN THE CARIBBEAN AREA

Country	Date Observed	Variety
Guyana	December 1974	HJ5741
Martinique	April 1975	HJ5741
Trinidad	April 1976	HJ5741
Jamaica	November 1976	HJ5741
Guadeloupe	June 1978	HJ5741
Florida (USA)	July 1978	CL49-200
Belize	July 1978	HJ5741
Venezuela	August 1978	B49119, V63-2
St. Kitts	September 1978	HJ5741
Cuba	November 1978	B42231
Panama	April 1979	B49119
Barbados	June 1979	B49119
Honduras	Early 1979	B42231, L60-14
Nicaragua	Early 1979	L60-14
Colombia	1979	B49119, CP57/603
Mexico	January 1980	MEX56-18, NCo310
Haiti	1980	–
Costa Rica	Early 1981	L60-14, NCo310
Guatemala	Early 1981	L60-14, NCo310
Puerto Rico	February 1981	PR1124
Dominican Republic	April 1981	CR6302, B42231
Louisiana (USA)	June 1981	CP65-357

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TABLE 3. PROGRESS TOWARDS THE ELIMINATION OF SMUT SUSCEPTIBLE VARIETIES IN THE CARIBBEAN

Country	Area under cane (Ha)	% area under susceptible varieties		Likely date for *complete control
		Initially	Now	
Guyana	48,200	37 (1974)	3 (1980)	1981
Martinique	–	–	–	1980/81
Trinidad	40,500	35 (1976)	2.5 (1981)	1982
Jamaica	48,600	42 (1976)	13 (1981)	1983
Guadeloupe	–	–	–	1982/83
St. Kitts	4,230	47 (1978)	29 (1980)	1984/85
Florida	144,000	14 (1978)	6 (1981)	After 1983
Belize	25,100	55 (1978)	40 (1981)	1986/87
Venezuela	85,000	–	–	–
Cuba	1,200,000	10 (1978)	–	1982
Panama	50,000	40 (1980)	35 (1981)	1987
Honduras	40,000	35 (1979)	28 (1981)	1984
Nicaragua	35,000	–	–	–
Barbados	16,200	9 (1979)	–	1981
Colombia	125,000	12 (1979)	12 (1981)	1984
Mexico	500,000	25 (1980)	–	1985
Haiti	14,500	–	–	–
Costa Rica	55,000	45 (1981)	45 (1981)	1988
Guatemala	50,000	–	–	–
Puerto Rico	48,500	3.5 (1981)	3.5 (1981)	–
Dominican Republic	178,500	10 (1981)	9 (1981)	1985
Louisiana	96,400	76 (1981)	76 (1981)	After 1987

* i.e. less than 0.5 per cent of area in susceptible varieties

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St. Kitts and Florida are intermediate, i.e. they will achieve complete control between 1983 and 1987. No report was received in respect of the other four countries mentioned in the table.

The variety situation will be discussed later after dealing with rust disease.

RUST DISEASE IN THE CARIBBEAN

Sugar cane rust disease caused by the fungus, *Puccinia melanocephala* H and P. Sydow., was first observed in the Western Hemisphere in July 1978 when an epiphytoxic was reported in the Cristobal Colon Mill area in the Dominican Republic affecting variety B4362. There are two pathogens causing rust disease in sugar cane (Egan, 1964) namely, *Puccinia kuehnii* Butl. and *P. melanocephala*. *P. kuehnii* has been known since the 1980's and has been regarded as a weak pathogen causing disease attacks of a transient nature and generally of little consequence. *P. melanocephala* was first reported as a sugar cane pathogen in 1949 (Patel, 1950) and it causes a more serious disease problem. *P. melanocephala* rust (hereafter simply 'rust') in only two years has now been observed in all but two of the sugar growing countries of the region (Table 4). Smut, in contrast, took nearly seven years to have spread throughout the region. Table 4 also shows B4362 predominating as the variety first infected, it being very highly susceptible.

In general the intensity of rust infection in a susceptible variety is related to age of the cane and less to seasonality and climate *per se.* When, however, the juvenille stage of cane coincides with cool and/or droughty conditions, extremely severe symptoms expression and retardation of growth and subsequent yield results (Burgess, 1980). Indeed, our experience in Jamaica is that any condition which prolongs the juvenile state of growth of susceptible varieties will worsen the effects of rust.

Since B4362 is by far the most important variety affected, most of the observations have been made with reference to it. This variety appears to escape infection for up to about eight weeks after cutting, and then becomes very seriously infected until around six to seven months of age. Thereafter, infection reduces and may even become altogether non-evident in cane of 12 months and older. The pattern in other less susceptible varieties is similar.

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TABLE 4. CHRONOLOGY OF RUST DISEASE IN THE CARIBBEAN

Country	Date Observed	Variety
Dominican Republic	July 1978	B4362, 090
Jamaica	September 1978	B4362, B51415
Guadeloupe	September 1978	B4362
Cuba	September 1978	B4362
Puerto Rico	October 1978	PR78-57, PR67-3129, B4362
Panama	November 1978	B4362
Mexico	January 1979	B4362, MEX70-241
Belize	January 1979	B59233
Honduras	January 1979	B4362
Venezuela	January 1979	B4362, CL41-223
Guatemala	March 1979	B4362, Q83, CP65-357
Costa Rica	March 1979	B4362, B50-377
Nicaragua	March 1979	B4362
Florida	March 1979	CP65-357, CL41-223
Haiti	March 1979	B4362, ODN-8
Colombia	April 1979	B4362, CP57-603
Trinidad	April 1979	B4362
Louisiana	June 1979	CP74-362, CP74-383
Texas	June 1979	LSI-43, L61-49
Barbados	August 1980	Tukuyu-2

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Status of Rust Control in Various Countries

As in the case of smut, total eradication is virtually impossible for much the same reasons given earlier. A summary of the progress in controlling rust in the countries of the region is given in Table 5, which shows that by 1982/83 most of the countries reporting will have reduced the area in susceptible varieties to 0.5 per cent. These are the Dominican Republic, Jamaica, Cuba, Honduras, Panama, Costa Rica and Trinidad. In Puerto Rico, Belize and Colombia initial percentages of cane in susceptible varieties were so low that replacement was almost immediately possible.

A feature of the rust epidemic has been the rapidity with which fields of susceptible varieties through a cane area became infected. It coming so prominently on the scene and over-lapping the smut epidemic, put even greater pressure on the variety replacement programmes in the region. In Jamaica, for example, the outbreak of the rust epidemic was so severe on B4362 that soon it resulted in the suspension of planting the variety on which we had been relying over the next two years to replace the highly smut susceptible HJ5741 which, at that time (1978), still occupied over 35 per cent of the cane area. Growers were not as understanding as would have been hoped, despite the 'flat out' efforts of the Sugar Industry Research Institute in getting replacement varieties and arranging and distributing seed material.

Cooperation among countries has been a feature of the campaign against rust (and smut). When rust arrived less was known about it than had been the case with smut; this of course, made the management of the disease more difficult. International cooperative efforts played a significant role, for example, in formulating strategies against rust based on the pooling of rapidly developing experiences within the region.

CONTROL MEASURES

The initial reactions to the smut and rust epidemics in many of the territories were to 'eradicate' them by destroying infected fields, and to adopt phytosanitary procedures such as restriction of movement of seed material, equipment and personnel from infected to other areas. Many prime stands of susceptible varieties were burnt and ploughed out (Young Kong, 1981). In Guyana smutted fields were even subjected to water therapy after reaping by

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TABLE 5. PROGRESS TOWARDS THE ELIMINATION OF RUST SUSCEPTIBLE VARIETIES IN THE CARIBBEAN

Country	Area under cane (Ha)	% Area Under Susceptible Varieties		Likely Date for *complete control
		Initially	Now	
Dominican Republic	178,500	32 (1978)	10.5 (1981)	1983
Jamaica	48,600	16 (1978)	5 (1981)	1983
Guadeloupe	–	–	–	–
Cuba	1,200,000	35 (1978)	–	1983
Puerto Rico	48,500	0.05 (1978)	0.6	1982
Panama	50,000	40 (1979)	15 (1981)	1983/84
Mexico	500,000	28 (1978)	–	–
Belize	25,100	1.5 (1979)	–	1982
Honduras	40,000	15 (1979)	10 (1981)	1982
Venezuela	85,000	38 (1978)	–	–
Guatemala	50,000	–	–	–
Costa Rica	55,000	2.7 (1979)	9 (1981)	1982/83
Florida	144,000	8.7 (1979)	2.2 (1981)	–
Haiti	14,500	–	–	–
Colombia	125,000	2.5 (1979)	1 (1981)	1982
Trinidad	40,500	2 (1979)	–	1982
Louisiana	96,400	–	–	–
Barbados	16,200	–	–	–

*i.e. less than 0.5% of area in susceptible varieties

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flooding prior to ploughing. These practices might have been effective if for example, the epidemic was being introduced by an imported cutting, and it soon became clear that such practices were to no avail since the infecting spore showers had produced fallout over wide areas, as indeed new showers would continue to do. In any event, by the time the disease symptoms became evident in a field, spores had most likely been widely disseminated from it.

In view of the futility of eradication attempts, industry-wide policies for managing the diseases were soon adopted within the countries of the region. The programmes developed for this management consisted of a combination of partial control or containment measures aimed at minimising disruption and economic loss. Some of these are:

a. rogue diseased shoots or stools
b. select healthy planting material
c. avoid planting varieties with only moderately resistant (MP) to smut in fields from which susceptible varieties are being replaced
d. if *c* must be done, treat the planting material with a fungicide
e. spray young fields of rust susceptible varieties with fungicide prior to the onset of "mature plant resistance"
f. discard the two topmost internodes from planting material of varieties MR to smut
g. practice pre-harvest burning of canefields
h. time the harvest or planting of rust susceptible varieties so as to avoid slow growth conditions during early stages, i.e. plant resistant varieties for ultimate control.

It should be remembered too that smut and rust are 'stress' diseases and therefore, a high level of husbandry is necessary to minimise yield loss.

Management of Epidemics

The definitive control of smut and rust is by planting resistant varieties. Because a cane crop cycle consists of one plant and a number of ratoons, immediate replacement of susceptible varieties is not practicable nor, for economic reasons, advisable. In the first case the acreage that can be replaced is limited by tillage capacity and opportunity days, and in some areas, by irrigation

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capacity; and by the availability of acceptable resistant replacement varieties. Then the rate of decline and order of yield loss of the diseased variety must be considered. It is around these parameters that industry-wide policies for the management of the disease were built. There are two main stages in the management programme namely:

- before the disease arrives – consisting of preparation
- after the disease arrives - consisting of containment in the short term, and replacement in the longer term

Preparation

Smut and rust spores are capable of being transmitted thousands of miles on wind currents and consequently, any susceptible variety in the path of the fallout can be expected to be infected if conditions for germination are favourable. The question is not if, but when the epidemics will strike. Preparation of the industry for the arrival of smut and rust infections must therefore, centre around the following:

Finding the disease through regular surveys, concentrating on known susceptible varieties, especially between two and seven months old. In the case of rust the symptoms are so obvious affecting practically every plant, that finding it is easy.

Building up supplies of resistant plant material. Determine resistance of commercial and promising varieties via testing in countries with the disease or, if possible, get information on the reaction of local varieties in countries where the diseases are present. Locate all sources of resistant commercial replacement varieties within the various areas of the industry. *Quantify* the seed material available on which to base the replanting programme. Establish well supervised pure stand nurseries.

Reducing land area planted to susceptible varieties. Aim to have only such area as may be replaced in one year.

Providing information to all levels of employees on the diseases to facilitate the above, especially finding an epidemic early. This also aids containment.

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Containment

Once a smut infection begins, efforts must be directed at reducing the amount of infectious materials – spores and whips – and maintaining sanitation procedures that will minimise re-infection and new infection. Efforts to achieve this should be undertaken by systematic, detailed and regular monthly roguing by trained crews of workers. Roguing consists of removing whips (beforerupture) and in the case of young fields, entire infected stools which are promptly placed in large plastic bags, the entire package being burnt outside the field.

An important facet of the survey and roguing exercises is the keeping of records. Field names, location and the number of whips taken at each roguing from each field must be recorded as the decision to replant is largely determined by the number of whips per acre, being the index of infection level. In Jamaica the threshold for replanting is 2,500 whips per acre (6,200 per hectare) or approximately 10 per cent stalk infection. In Rhodesia (James, 1972) 10 per cent is also used, and in Guyana three per cent. The effectiveness of roguing is questioned by Whittle (1980) and others (Presley, Perdomo and Ayats, 1978) and while the logic of the arguments is clear, our own experience in Jamaica is that roguing has been effective in maintaining yield levels of HJ5741.

It is also well documented from controlled experiments that pre-harvest burning reduces the rate of build-up of smut (Gosnell and Lonsdale, 1977) and this practice is advocated.

In the case of rust there is enough evidence (Scarlett, 1979 and Bachchhav, Hapace, Patel, Ghure, 1978) to justify fungicidal treatment of young fields of rust-susceptible varieties in an effort to delay infection by a few weeks; however, roguing is quite impracticable.

Variety Replacement

The foundation for variety replacement is a good breeding and selection programme, which can be relied upon to produce acceptable replacement resistant varieties. Where the industry is not centrally controlled, an effective extension service will be most helpful. Once replacements are on hand the multiplication and distribution and the purity of seed material must be ensured. The growers must be given detailed information on variety adaptation and other

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features. The co-ordination and general management of this accelerated programme must be the responsibility of an able and uncompromising officer. Co-operation and mutual assistance among growers in respect of adequately distributing stocks of seed material is also invaluable.

The need for a replacement programme to be realistic is important. It must be managed so as to eliminate susceptibles with minimum economic loss and disruption to the enterprise. In Jamaica a programme of incentives was instituted to guide the rate of replacement according to action levels worked out by the Sugar Industry Research Institute. A priority order of fields to replant was issued based mainly on variety and ratoon cycle. Type of fields to replant and the variety for each area of the industry were widely distributed to growers in pamphlets and leaflet form, as well as orally. The programme also included incentives for Record Keeping in the case of smut surveys and for establishment of nurseries of resistant varieties.

ECONOMIC IMPACT OF SMUT AND RUST

The economic impact of a disease is based upon:

- the area in susceptible varieties
- direct loss in yield, i.e. resulting from the level of infection
- relative yield of replacement varieties
- loss due to early replanting
- cost of control procedures and aids

The quantification of yield loss is always difficult, yet it is a prime essential in any rational attempt at economic control of a disease. Estimates of yield loss are often complexed by climatic and seasonal factors and interactions, soil conditions and level of husbandry.

Losses Due to Smut

Direct loss of yield resulting from smut infection is caused not only to lowered cane yield due to reduced nembers and length of millable stalks, but also to reduced sucrose per cent fibre. Whittle (Lii-Jang Liu, 1981) has proposed that for every one per cent stalk infection there is a direct cane yield loss of 0.9

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per cent. This equates to about 6 to 8 tons of cane per hectare at 10 per cent stalk infection using the broad average yields for the countries of the region.

The direct loss potential of highly susceptible varieties like HJ5741 is likely to approach 100 per cent over time. However, because of the replacement policies in the Caribbean region, very high orders of loss have only rarely been seen. In Belize (Cawich, 1981) individual field losses have been estimated at 34 per cent and 50 per cent. In Jamaica highest losses on HJ5741 have been around 60 per cent after four years infection and under depressed growing conditions. In general however, because of the replacement and control measures, direct loss in Jamaica (and perhaps in the Caribbean as well) have been averaged around 10 to 12 per cent on the worst 40 per cent of infected fields, and around four to five per cent on the rest – for an overall average of six to seven per cent. Thus, in an industry of 50,000 hectares with an initial 45 per cent susceptible varieties (20 to 25 per cent after three years) direct loss would be about 1.6 per cent of total yield or about 6,000 tonnes sugar per year after the disease has become widespread, say two to three years after initial infection. Prior to that direct loss would have been negligible.

Of even greater importance can be indirect loss due to replacement of high yielding varieties like HJ5741 by appreciably lower yielding ones. In the case of Guyana, Whittle (1980) has estimated this indirect loss to be 15,000 tonnes per year where B41227 yielding 1.25 tonnes per hectare less, replaced HJ5741 and D414/60 on 30 per cent of that 48,000 hectare industry. In Jamaica, the difference can be shown to be 0.5 tonne per hectare (HJ5741 versus the combination of replacements) and the loss, around 9,500 tonnes per year after total replacement. This could have been worse if the initial replacements – B41227, B51129 and B4362 – had not been backed up by UCW5465 and after a few years given way, substantially, to new higher yielding varieties like BJ7015.

Loss due to early replanting *per se* of smutted fields are not thought to be significant. However, the cost of smut control procedures and aids are estimated at US$1 to US$1.25 per tonne sugar for the region.

An indication of the impact of smut on the individual countries can be made by reference to the data in Table 3 in light of the discussion above.

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Losses Due to Rust

Direct loss due to rust infection *per se* results only from reduced cane yield as sucrose content (Burgess, 1980) is apparently unaffected. Damage from rust mainly occurs between six and 22 weeks and is characterised by premature death of lower leaves, reduced stalk elongation rate and possibly reduced tillering and stalk diameter, the overall intensity of these deleterious effects being aggravated by poor growing conditions where as few as three green leaves may remain on each stalk. These stress conditions include infertility, moisture stress, weediness.

Estimates of yield loss tend to be exaggerated, perhaps because of the spectacular nature of the disease symptoms. In fact, losses can be greatly complexed by the interaction of climatic and seasonal factors such as cool nights and short, cloudy days. An analysis by the author (Shaw, 1979) has shown loss due largely to these interactions as being 19 per cent whilst loss due to the infection *per se* was 12 per cent.

Within the Caribbean region estimates of yield loss have ranged from seven per cent average, 15 per cent high in Puerto Rico (Lii-Jang Liu, 1981) to 15 to 40 per cent in the Dominican Republic depending on climate (Bernard, 1981). In Cuba losses of one million tonnes sugar in one year are reputed to have been attributed to rust on the highly susceptible variety B4362 occupying one-third of their cane area. Whittle (1980) estimates loss of 20 per cent in Cuba, for an overall seven per cent loss on their sugar production, i.e. approaching one-half million tonnes. Whittle and Redman (1980) also estimate 20 per cent loss of yield in the Dominican Republic which also has one-third of their area in B4362 for seven per cent overall loss in yield. Dean (1981) gives estimated average loss of around 15 per cent ranging up to 30 per cent during 1980/81 in Florida on C141-223 which occupies only 2.2 per cent of the cane area.

In Jamaica estimates of loss on B4362 assessed by different methods vary from 10 to 14 per cent to 13 and eight per cent. It would seem, therefore, that about 12 per cent loss in yield is a reasonable average and with about five per cent of the industry being planted to B4362 for the 1981 crop the loss was less than 0.6 per cent overall since many fields using recommended disease management practices almost escaped infection.

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Indirect loss due to replacement by other varieties is not expected to be great since the main highly susceptible variety – B4362 – was not as relatively outstanding as say, HJ5741. Expenditure on control procedures such as fungicidal treatments appears to have been small as the practice was not generally accepted. Loss from premature replanting is also undoubtedly and important source of financial loss in countries which had high percentages of B4362 reduced quickly, such as Panama, Cuba, Venezuela, Costa Rica, Mexico and the Dominican Republic.

VARIETY SITUATION

The combined replacement programme required by the smut and rust epidemics in the Caribbean region has restricted the choice of acceptable resistant varieties and undoubtedly magnified the loss due to the lower yields of many replacements. Nor does the matter end there, for with the diseases becoming "endemic", notwithstanding complete control, their presence will represent a continuing pressure on the breeding and selection programmes in the region. The production of superior varieties will probably therefore be less, especially in the light of the increasing list of dangerous diseases and pests. When this fact is viewed against the present census of varieties which occupy 10 per cent or more of individual industries (Table 6) an unsatisfactory situation is apparent. The census shows that in the 17 industries for which data are available:

- only Florida has four varieties resistant to smut and rust
- ten industries have either one or no such reliable varieties
- five industries have two such varieties
- four industries have 60 per cent or more of their cane area in a single variety (and two have 80 per cent)
- 21 of the 32 varieties in use in the countries were apparently released prior to 1969.

So far as new resistant varieties are concerned the situation is unclear. It would appear however that Jamaica with four good prospects (two very good) and Florida may be in the best position. In fact, in Jamaica 80 per cent of the replant acreage for the 1981/82 crop will use these four varieties. Guyana is expanding DB51362 (1.1 per cent at present) and DB66113 (13 per cent). Trinidad, Mexico and Louisiana also have one or two new prospects.

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TABLE 6. MAJOR CANE VARIETIES IN SOME CARIBBEAN COUNTRIES

Country	Major Varieties (over 10%)
Barbados	B62163 (62)*, B63118 (12)
Belize	POJ2878 (21), B5721 (17), PR1048 (15), HJ5741 (13) B52298 (10)
Colombia	POJ2878 (80)
Costa Rica	L6014, NCo310, H37/1933, B4362
Dominican Republic	PR980 (31), CP52-43 (28), CR6101 (17)
Florida	CP63-588 (26), CP70-1133 (14), CP56-59 (12) CI 54-378 (10)
Guatemala	PPOK, B4362, B49119
Guyana	B41227 (40), DB66113 (13), D38/57 (9)
Honduras	NCo310, L6014, B4362
Jamaica	UCW5465 (36), B41227 (14), HJ5741 (11) B51129 (10)
Louisiana	CP65-357 (66), CP70-321 (9)
Mexico	NCo310, B4362, Co213, MEX54/81
Nicaragua	NCo310, B3439, PR980
Panama	B54142 (35), B49119 (35), B4362 (15)
Puerto Rico	PR980 (40), PR1028 (14)
Trinidad	B41227 (80)
Venezuela	B4362, B49119, CP57-603

*Percentage of cane area

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Variety Susceptibility Rating

When smut arrived, only a few of the varieties in use in the Caribbean had been given susceptibility ratings (from outside the region). Very soon Guyana began systematic ratings and was followed by Jamaica after the disease arrived there. Several other countries did likewise following their being infected. Co-operative efforts and general asistance were the rule with Jamaica, for example, assisting the USDA and Cuba in formal arrangements.

Testing and rating procedures for smut susceptibility adopted were soon standardized on a 0–9 scale based on a per cent stalk infection, replacing the stool infection ratings. Testing is now done by growing statistical numbers of buds following inoculation by dipping into a smut spore suspension. Ratings have proved reliable guides to field infection levels in general, much more so than ratings of local varieties obtained from countries outside the region.

In case of rust, tesing procudures used are field exposure trials, for example, alternative rows of susceptible standard and test varieties. The exception is C.E.A. in the Dominican Republic where foliar inoculation is done.

Ratings obtained are often voluntarily made available to other countries within the region.

Breeding/Selection Programmes

As the definitive method of controlling sugar cane diseases of serious consequence is almost exclusively variety replacement, the importance of breeding is obvious. So far as smut is concerend the heridity of resistance is uncertain (Ladd, Heinz and Meyer, 1974) and even highly susceptible parents can themselves produce a fair proportion of highly resistant progeny. Consequently, no drastic alteration of the genetic base available to breeding stations is deemed necessary and it is only necessary to increase the number of seedlings to allow a greater statistical chance of selection of resistance (and other criteria).

Screening for smut should best be done at an early selection stage consistent with the considered ability to cope with the numbers of clones. Most selection programmes appear to favour the third stage.

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One serious obstacle to control of diseases by variety replacement, and more generally the availability of varieties, is the lack of breeding and even fair variety selection facilities in most of the countries. This situation will need to be upgraded if these countries are to have a chance of finding replacement varieties on a timely basis – a position which increases in importance from year to year. In the meantime an urgent need will continue to be improved quarantine arrangements which will more speedily but safely allow the movement of varieties within the region. The willingness to cooperate for mutual benefit has been aptly demonstrated during the last few years since the advent of smut and rust.

SUMMARY

The advent of smut and rust diseases of sugar cane during the last six years into the Caribbean sugar industries posed serious threats to their viability. Smut is present in all and rust in all but two of the 22 industries. Smut was usually first observed on the very highly susceptible variety, HJ5741, and in other industries in its absence on B49119, L60-14, NCo310 and B42231. Rust was most often found on B4362, and spread throught the region very much more rapidly than smut.

The progress of control of the diseases is outlined and dates for achieving complete control are given. Control measures are discussed with emphasis on the management of the epidemics so as to minimise economic loss. Management practices were based on eventual control by replacement of susceptible varieties with interim containment of infection levels and of losses. Losses to smut were mostly due to replacement of high yielding varieties with older less prolific ones, and to direct losses resulting from the infection. Losses to rust were mostly direct.

The variety situation in the region is considered to be generally unsatisfactory. The susceptibility rating procedures used in the region are described.

Variety selection and attendant necessary quarantine facilities are advised especially in light of increasing incidence of dangerous diseases.

ACKNOWLEDGEMENTS

I am happy to express my thanks to the technologists in the various countries who found it possible to respond to my request for information and to

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those as well who may have been frustrated by the vagaries of the international postal services.

The data given in Tables 2-6 were compiled largely from the replies as indicated below:

Barbados, Guadeloupe Martinique	Mr. D.I.T. Walker West Indies Central Sugarcane Breeding Station Barbados
Colombia, Costa Rica Panama, Guatemala Mexico, Nicaragua Venezuela	Mr. Eduardo Esquivel GEPLACEA Secretariat Mexico DF. Mexico
Dominican Republic	Dr. F.H. Redman Central Boma Republica Dominicana Dr. F.A. Bernard Conseige Estatal del Azucar Division Exp. Duquesa Republica Dominicana
Florida, U.S.A.	Dr. Jack Dean USDA Sugarcane Field Station Canal Point, Florida, U.S.A.
Honduras	Ing. Juan Herrera
Louisiana, U.S.A.	Dr. James Irvine USDA Sugarcane Field Laboratory Houma, Louisiana, U.S.A.
Puerto Rico	Dr. Lii-Jang Liu Agric. Exp. Stn. UPR, Rio Piedras, Puerto Rico
Trinidad	Mr. A.F. Donelan Caroni Research Station Carapichaima, Trinidad

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PRESENT STATUS OF RESEARCH OF 'HARTROT' OF COCONUT IN SURINAME AND PROPOSAL FOR A REGIONAL STRATEGY FOR CONTROL

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INTRODUCTION

Coconut and oil palm are important crops of Latin America and the Caribbean Region. Many countries in the region have expanded the acreage under these crops or are planning to do so with a view to become self-sufficient in edible oils or to avail the export opportunities. But there are potential dangers affecting the progress of these palm cultures in this region. We mention especially the disease known as 'hartrot' or 'fatal wilt' and the pest *Castnia daedalus* Cr.

The disease 'hartrot' was first reported during 1908 in Suriname (Drost, 1908). It is no longer confined to this country but is now widespread in South America and the Caribbean Region. Considerable losses due to withering caused by this desease in African oil palm *(Elaeis guineensis)* have been reported from Colombia, Peru and Ecuador (FAO, 1980). This withering that ends up in a complete killing of the affected plants is known as 'Marchitez sorpresiva' in Spanish and 'wilt' in English. Flagellates similar to those observed in coconuts affected by this disease have been found in those plants. During the Fifth Session of the FAO Technical Working Party on Coconut Production, Protection and Processing held in Manila, Phillippines in December 1979, concern was expressed on this disease.

The disease itself has been very poorly understood since little is known about the host-pathogen relationship. Reports of research done on this disease (McGhee and McGhee, 1979; Parthasarathy, Van Slobbe and Soudant, 1976; Parthasarathy and Van Slobbe, 1978; Van Slobbe, Parthasarathy and Hensen, 1978) though significant are very preliminary in nature. More basic work on the host plants, insect vector or vectors and the presumed pathogen *(Phyto-*

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monas staheli) needs to be done urgently to know the epidemiology of the disease and to find out effective methods of control.

This disease is characterised by the yellowing of leaves starting from the tip of the oldest and then affecting progressively the younger ones. This is followed by dropping of nut, especially the immature ones which fall initially, and are followed by the mature ones. The next step is a blackening of female flowers and turning to brown of the younger inflorescences. Finally, a rot of the spear takes place and the spear leaf topples over emitting a foul smell. The apical region also rots with a similar odour. The initial symptom ending with the complete death of the plant takes place in a period of six to twelve weeks. This disease has the potential for rapid spread.

Castnia deadalus, a lepidopterous trunk borer, is another major cause for damage of coconut and also oil palm in several South American countries. Attack of oil palms, however, is less known (Shuiling and Van Dinther, 1980). The larvae attack the fruit bunches in addition to the trunk and bases of the petioles. The fedding of larvae in fruit bunches can lead to considerable loss in production. Older larvae tunnelling the trunk may result in large cavities under the stem apex which may cause the death of the palm. Losses of up to 40 per cent of production of bunches have been reported from some plantations in Peru. This insect is also considered as a serious pest of oil palm in Brazil and Suriname. In some coconut plantations in Suriname, the insect affects up to 96 per cent of the trees.

Thus, the existence of palm cultures in these areas depends on identifying effective measures of control for these maladies as early as possible.

PRESENT STATUS OF RESEARCH OF 'HARTROT' OF COCONUT IN SURINAME

In our attempts to control 'hartrot' of coconut in Surniame, field experiments were conducted with different varieties of coconut. We evaluated the extent of susceptibility, tried chemical treatments with insecticides, fungicides and nematicides as well as cultural treatments like weeding and no weeding in order to find out their influence on the disease incidence.

The result so far obtained indicate that there are varying degrees of susceptibility to 'hartrot' between varieties of coconut. Suriname Tall is found

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to be the most resistant (Alexander, 1979). This may be due to the acquired resistance of "Suriname Tall" in the trial. They are the seedlings from the surviving healthy palms from an endemic area of this disease. Similarly, hybrids with "Suriname Tall" as one of the parents show significant tolerance to the disease (Alexander, 1981). The results also indicate that the incidence of disease commences even before the bearing stage of the coconut.

In the case of chemical treatments, only Endrin 0.1 per cent as an insecticide once in every two months proved to be successfully controlling the disease incidence significantly (Alexander, 1981). Similar results were obtained by this treatment to control 'Marchitez' of oil palm (Lopez, Genty and Ollagnier, 1975). This may be due to the elimination of the suspected insect vectors (Griffith, 1980).

Of the cultural treatments, complete weed control in the coconut plots seems to be the effective treatment against the disease. By eliminating weeds the suspected source of the pathogen and the food for the vectors (Griffith, 1980) are probably destroyed. This results in a decrease of the disease incidence.

PROBLEMS OF CASTNIA IN SURINAME

It has been noticed that the life cycle of *Castnia* in Suriname is different from that in Brazil. Therefore, the schedule of control measures adopted for this pest in Brazil and elsewhere is not applicable in Suriname (Bronkhorst, pers. comm. 1981). Continued use of the insecticides - Endrin and Monocrotophos - may give rise to problems of residual toxicity in the final products. The insects may also develop resistance in the long run. Hence, it is felt that further research of this pest ot circumvent the issues mentioned above has to be undertaken.

PROPOSAL FOR A REGIONAL STRATEGY FOR CONTROL

At present there is no internation or regional research centre engaged in conducting multi-disciplinary research on all aspects of economically important palms of this region. Individual countries with their limited resources carry out some applied research on the problems when it affects them.

Moreover, there is no systematic exchange of information regarding problems and work done in different countries. Hence, it is felt that after

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TABLE 1. INCIDENCE OF 'HARTROT' ON SOME COCONUT VARIETIES PLANTED IN 1970

Variety	Number of Plants	Percent Dead
Malayan Dwarf	70	13
Ceylon Dwarf (green)	70	50
Ceylon Dwarf (orange)	70	17
Ceylon Dwarf (yellow)	70	19
Suriname Dwarf	81	60
Suriname Tall	32	6

TABLE 2. INCIDENCE OF 'HARTROT' ON SOME COCONUT VARIETIES PLANTED IN APRIL 1977

Variety	Number of Plants	Percent Dead
Malayan Dwarf	171	33
Ceylon Dwarf	124	38
Suriname Dwarf	125	44
Hybrid (SD x SH)	76	15*

*Significant at 5% level

LSD = 12.7 for varieties

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TABLE 3. INCIDENCE OF 'HARTROT' IN COCONUT PALMS PLANTED IN APRIL 1977 WITH DIFFERENT CHEMICAL AND CULTURAL TREATMENTS

Treatments	Number of Plants	Percent Dead
Chemical:		
Endrin (Insecticide)	96	12**
Furadan (Nematicide)	96	41
Chestnut Compound (Fungicide)	92	35
Control	88	44
Cultural:		
Complete Weed Control	64	7**
No Weed Control	60	62

**Significant at 1% level

LSD = 21.5 for treatments

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carefully evaluating the importance of coconut and oil palm to the region in terms of area under these crops, its production, employment, income generation and nutritional contribution, a Regional Research Centre for coconut and oil palm as a long term plan, should be considered for International funding.

If there is a support to establish such a Regional Research Centre we would like to put foward the following criteria for selecting the location.

1. Previous record of work.
2. Willingness of the host country (making the land and other facilities available for the Centre) and,
3. Conditions suitable for establishing such a Centre, namely, existence of problems common to these countries in an endemic manner and field and other facilities for carrying out research.

We are aware that creation of such a Centre could take several years. Moreover, we are also convinced that even with the establishment of a Regional Centre there will be a need for specific sub-centres, one of them being for "plant protection". The most challenging problems for protection are 'hartrot' disease and *Castnia* control. We strongly suggest that studies on 'hartrot' be approached with twin goals, one on basic studies and one on applied aspects. In the case of *Castnia*, basic studies on its biology under different conditions might be required to control the pest.

In both cases it will be worthwhile to explore the possibilities of bio-control of the organisms involved. Studies of varietal resistance to control these maladies may be worthwhile in order to find a permanent solution. It is strongly suggested that Suriname be the appropriate location for the Plant Protection Centre for coconut and oil palm for the following reasons.

The Agricultural Experiment Station has had a tradition of conducting outstanding research on problems involving plant protection since Stahel's contributions during the 1930's. At the moment the Experiment Station has a team consisting of a Virologist, a Bacteriologist, an Entomologist and an Agronomist to carry on both applied and basic research on 'hartrot' as well as on pests like *Castnia*. Since the presumed pathogen for 'hartrot' *Phytomonas* and the pest *Castnia* are endemic in Suriname, it would be reasonable to conduct experiments on various aspects of these maladies there hoping to find ways

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and methods for their control. Furthermore, it is understood that the Government of Suriname will have several test-fields available to the countries of the region to conduct experiments of mutual interest. Besides, Suriname also has a major investment in oil palms and is on its way to becoming an important producer of palm oil.

The resources required to establish and maintain a Plant Protection Centre for coconut and oil palm with regional dimensions have to be worked out and may take some time. In the meantime, it is our proposal to upgrade the existing facilities in Suriname in order to maintain the continuity of the work. Upgrading the facilities can be carried out with the aid of the IICA. Upgrading will require the following:-

Personnel

1. It is recommended that the Plant Protection Centre in Suriname be administered by the Ministry of Agriculture in Suriname and be headed by a Coordinator (Ph. D) *who will not only contribute to research* but coordinate research for the region. This person must have an excellent background in the cultivation of economically important palms. He must also have sufficient experience, have a wide scientific background and management capacity for the coordination of research between the different countries.

2. As mentioned earlier, a team consisting of a Virologist, a Bacteriologist, an Entomologist and a Agronomist is already assisting in research and control attempts of 'hartrot' and *Castnia.* Except for the Agronomist, the other research workers contribute only 10 to 50 per cent of their time to research on palm diseases. Hence, a Research Specialist post may be created to assist the Coordinator as well as the research team in routine research and experiments. This post may be contributed by the Suriname Government. The Research Specialist should be an Entomologist trained in biocontrol with a background in parasitology and protozoology.

Building Facilities

An additional wing may be constructed to the existing laboratory of the bacteriologist to house the equipment and personnel involved in the project. Thus the efficiency and the productivity of the project can be increased. This additional wing may cost US$50,000 and can be planned for 1983.

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Equipment Needed

1. Field microscope to study flagellates and other micro-organisms in the field. US$3,000
2. Digital analyzer system for rapid and accurate measurement of biological material. US$8,000
3. Sliding microtome (Reichert). US$5,000
4. One binocular dissecting microscope. US$1,500
5. Hot cold incubator. US$7,000
6. Leitz phase contrast microscope. US$10,000
7. pH meter. US$500
8. Wild binocular microscope. US$3,000
9. Photomicrographic attachment. US$1,000
10. One vehicle (Land Rover). US20,000

Other Items

Travel funds for consultants and other outside personnel connected with the project. US$10,000

On-the-job training and travel expenses for scientists connected with the project. US$10,000

Supply Needs

Chemicals, drugs, enzymes, glassware, photographic supplies, sterilization needs etc. US$10,000 plus 15 per cent a year every additional year

Suriname's Contribution to the Project

Personnel	Time	Remarks
1. Agronomist	100%	
2. Research Specialist	100%	Not yet appointed
3. Virologist	25%	
4. Bacteriologist	50%	

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5. Entomologist 50%
6. Parasitologist 10%
7. Rest (field workers-4) 100%

Equipment

1. Oven
2. Two refrigerators
3. Steriliser

SUMMARY

In Suriname, 'hartrot' of coconut was initially reported in 1908 but only in 1976 was the fagellate *Phytomonas* identified in the phloem of the diseased oalms. From the research conducted in Suriname, it has been possible to identify some preventive measures to check the disease these include:- periodical application of the insecticide Endrin around the coconut palms; complete weed control in groves and, using more tolerant varieties like Suriname tall and hybrids with Suriname Tall as one of the parents.

Nothing is known about the fundamental aspects of the disease. At present, there is no international or regional research centre engaged in conducting multi-disciplinary research on all aspects of important palms. With the establishment of a Regional Centre, there will be need for specific sub-centres, one of them being for *Plant Protection*. The most challenging problems for protection are 'hartrot' disease and *Castnia* control. Suriname is an appropriate location for a Plant protection Research Centre for coconut and oil palm.

As an immediate step, upgrading of the existing facilities in Suriname is needed in order to maintain the continuity of the work. This requires a Coordinator and Research Specialist, besides the existing Virologist, Bacteriologist, Entonomologist and Agronomist. Furthermore, additional laboratory facilities and equipment are needed.

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THE STATUS OF MOKO DISEASE IN GRENADA AND APPROACHES TO ITS CONTROL

L. Winston Small, *Plant Pathologist*

Systems
Barbados

INTRODUCTION

Moko, or bacterial wilt disease of bananas was first recorded in 1840 in Guyana by Schomburgh. The causal organism is *Pseudomonas solanacearum*, a ubiquitous parasite of solanaceous crops. However, the strains which attack commercial bananas are apparently restricted to the western hemisphere and the Phillipines. These strains are classified in race two of the three races of the organism. Within race two, the strains most commonly attacking Musa species are D, B, SFR and H.

Prior to February 1978, Moko had only been recorded in two Anglophone West Indian territories: Guyana and Trinidad. Then D.K. Cronshaw and J.E. Edmunds of WINBAN reported the occurrence of the SFR strain of Moko on bananas and bluggoes in the northernmost parish of Grenada (Cronshaw and Edmunds, 1980).

Moko is a disease of great economic importance. It is credited with the dubious honour of being the major contributory factor to the decline of the banana industry in Trinidad. Its effect has been noted in Central America as being most severe on small holdings and less so on large plantations. For such plantations, unlike small holdings, have the resources to adequately carry out the costly control measures necessary to keep the disease in check. Such control measures involve regular surveys of lands for disease Musa species; eradication of diseased and buffer zone trees; control of movement of possibly disease planting material; and replacement of most susceptible varieties (e.g. bluggoe) by less susceptible ones (e.g. Pelipito).

This paper seeks to describe certain aspects of the status of moko disease in Grenada and the work carried out in Grenada in late 1980 to effect control of the disease.

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THE STATUS OF MOKO IN GRENADA

Following the initial visit of the WINBAN scientists to Grenada in Februrary 1978, during which visit the presence of moko disease was confirmed, Dr. D.K. Cronshaw visited Grenada in June 1978 and trained local Extension Officers in the recognition of Moko disease symptoms. He also organised an island-wide survey which indicated that the disease was confined to the parish of St. Patricks in an area of approximately 4.9 km^2 roughly bounded lines joining Snell Hall Estate, Plaisance Estate and Chantimelle.

A progress report by Mr. S.D. Law, local officer in charge of the Moko disease survey and eradication effort, indicated that in October 1978 the disease was essentially still confined to the area above, but that there were possibly small pockets of infection in the following areas outside that zone, *viz:* Tuilleries, Birchgrove, Pyrenees, Dry River, Grand Fond and Richmond.

In June 1979, Dr. Cronshaw again made a brief survey of the disease prevalence and confirmed its presence at Crayfish which is slightly outside the triangular infected zone and La Taste and Mr. Rich which are on the edges of that zone.

Up to June 1979, therefore, it appeared that the disease was generally confined to the small triangular area in St. Patricks parish with small pockets outside this area but still in St. Patricks, and others in St. Andrews up to 15 km outside the infected zone.

Between March to April 1980, a comprehensive island-wide survey was carried out by Extension Officers trained in the detection of Moko disease. This survey indicated that Moko was present on 120 holdings in an area roughly nine times the size of the 1978 triangular disease zone in St. Patricks. Small pockets of the disease were noted at some distance from the diseased zone at Mt. Stanhope in the parish of St. Mark, Florida, Plaisance and Belvidere in St. Johns and Beauregard in St. Andrews.

A superficial comparison of the 1979 and 1980 survey data may indicate that the disease spread very rapidly during the ensuing period. However, it is my view that this spread is apparent only and not real. Moko most likely existed in the extended area during the previous years but remained undetected.

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This is quite understandable in that, prior to 1980, the farmers and to some extent the Extension Officer also, had little knowledge of Moko disease and would mistakenly tend to ascribe Moko symptoms to those of Panama disease, a problem which has been recognised in Grenada for sometime now. In addition, the potential danger of Moko to the Grenada banana industry did not appear to have been generally appreciated by most sectors of the community and thus the general public did not report suspicious symptoms to the GBCS or Ministry of Agriculture personnel, and finally, surveys carried out prior to March 1980 were limited in terms of manpower and the time allocated to them.

In mid-July 1980, the author undertook a short-term FAO consultancy (TCP/GRN/890IM) to design and lead the implementation of an eradication programme for Moko disease in Grenada. Since time was severely limited in this consultancy, and the March survey was quite extensive, island-wide surveys were not attempted. Instead, survey teams were recruited and trained to carry out intensive disease surveys initially on the fringes of the infected zone and moving inwards. A massive public relations campaign was also designed and carried out to make all Grenadians aware of the various aspects of the disease and to impress farmers to search for Moko on their properties and report its incidence to the Moko Control Office. The survey teams then visited holdings from which reports of possible Moko incidence had come and made detailed surveys in those areas.

Surveys have been carried out in the above manner on a continuous basis since July 1980. At July 1981, the disease appears to be generally confined to the 1980 disease zone with small additional pockets noted only in the Telescope, Dunfermline and Nianganfoix districts outside this zone. These pockets are, in all cases, near to existing pockets or to the already demarcated infection zone. No confirmed cases of Moko have been found in the southern portion of Grenada.

ERADICATION OF MOKO

Eradication of disease and buffer zone mats in the triangular infected zone commenced on 17th. July, 1978, using the Roguing out/Diesel oil method with an eradication team initially under the direction Mr. S.D. Law. During the period 17th. July to 31st. October, 1978, 29 holdings were treated and 5,580 mats destroyed. Following this, Mr. Law was seconded to WINBAN

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and the eradication effort was left with no technical direction. Between October 1978 and March 1980, 16,642 mats were eradicated. However, the eradication effort suffered from a number of deficiencies:-

1. The diesel oil was generally used most sparingly and was often unavailable and so an appreciable incidence of regrowth of 'eradicated' mats was noted.

2. Weeds in the buffer zone were not controlled.

3. Insecticide spraying of possible vectors was not carried out.

4. Destruction of buffer mats was not carried out as rigorously as was recommended because of complaints by farmers who could not appreciate the necessity for having apparently healthy trees destroyed.

5. There was no technical supervision to ensure that the eradication procedure was properly carried out on a day-to-day basis.

In July 1980, on the institution of the FAO-TCP project, an attempt was made to correct some of the deficiencies above in the roguing-out method. An adequate supply of diesel oil was obtained; workers were instructed to use standard quantities of diesel per mat; weeds in the buffer zone and insect were controlled by use of chemical sprays; and a trained supervisor was assigned to the day-to-day eradication programme.

During July and August, two experiments were conducted to identify an alternative eradication method using injections of the herbicides: Roundup (Glyphosate) and 2, 4-D. In late August, at the end of the first phase of the consultancy, it appeared that the Roundup injection method provided a viable alternative to the diesel roguing-out method and this method was accordingly introduced.

Between August 1978 and June 1980, 20,716 mats were treated in the eradication programme; during the FAO consultancy period (mid-July to December 1980), 41,128 mats were eliminated and between January to July 1981, 34,598 mats have been elimated. The relatively low numbers of mats eradicated in the first eradication phase may be mainly ascribed to:-

1. the relatively small team involved

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2. the use of the roguing-out method
3. frequent unavailability of supplies

The relatively high numbers eradicated during the consultancy period may be mainly due to the use of the fast Roundup method, and larger and better motivated teams. The relative decrease of eradicated mats in the post consultancy period could be ascribed mainly to problems in supply of Roundup and initial problems with rapidly deteriorating washers of the meat pumps used to inject Roundup into the banana tissues.

Prior estimates of numbers of mats to be eliminated have consistently underestimated actual numbers of mats eradicated when joint survey and eradication teams visit Moko infested holdings. The March 1980 survey gave an estimate of 25,000 mats to be destroyed. This figure was quickly passed during the first three months of the consultancy. In August 1980 the writer made a rough estimate of 75,000 more mats to be destroyed, however, between July 1980 and July 1981, 75,726 mats have been destroyed and Mr. James Marrast in July 1981 estimated that a further 15,000 mats would have to be eliminated to complete this phase of the programme.

THE ERADICATION METHODS

The roguing-out method used in Grenada is carried out as follows:-

The worker uproots the diseased or buffer zone mats using a mattock. Then, using a mattock or a cutlass, the corms and pseudostems are split into small fragments in the area from which the mat was uprooted and approximately 600 mls of diesel oil per pseudostem is poured on to the *Musa* fragments. Appropriate methods of sanitation of workers' apparel and implements are carried out.

The Roundup method developed by the writer is carried out as follows:-

Diseased or buffer zone mats are identified by trained survey staff. Eradication workers then inject approximately 50 mls per pseudostem of a four per cent solution of Roundup (Glyphosate) into the diseased or buffer zone mat using a "Morton" meat pump. Other workers spray diseased and buffer zone mats with a recommended insecticide and weeds in the buffer zone with a Gramoxone/Reglone mixture at the manufacturer's recommended rates. Appropriate sanitation is also carried out.

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Roundup, obtainable from Monsanto Chemical Co., has as its active ingredient 41 per cent of the isopropylamine salt of N- (Phosphonomethyl) Glycine. Roundup was selected as the herbicide for the eradication method mainly because of its outstanding attributes of symplastic systemicity and herbicidal effectiveness on a variety of weeds. The vast preponderance of intercropping in bananas in Grenada rendered it unlikely that a berbicide spray programme could have been feasible, and so the injection technique was tried. Injections with standard syringes were extremely difficult in spite of the herbaceous nature of the banana pseudostem, and so meat pumps, developed for injection salt solutions into meat for preparing hams were utilised. The main disadvantage of the meat pump injector was that the chemical caused rapid deterioration of washers which had to be replaced on a regular basis. However, such pumps were used for over six months with good results. Mr. Everton Ambrose of WINBAN has recently introduced a much more efficient injector, 'The Spot Gun', one charge of which is capable of treating 348 pseudostems.

The Roundup method is superior to the roguing-out one in a number of ways; relatively little effort is required of the workers who, in any case, have to traverse very difficult terrain; the method is much quicker and more economical than the roguing-out method despite the high cost of the Roundup; and the injection technique minimises contact between workers and diseased plants, thereby reducing the likelihood of spread of the disease. The Roundup method, however, has some disadvantages; workers in this method need a greater amount of skill and judgement than would be required for a roguing-out method. Also, in some cases, treated plants may take up to five weeks to die in which time there is some possibility of spread of the disease. Further research is needed on such aspects of the Round-up method as the survival of the bacterium with time after the Roundup treatment is initiated and the effect of soil conditions on the length of survival of banana plants after treatment.

OTHER ASPECTS OF THE CONTROL OF MOKO DISEASE

During the consultancy it was stressed that there was some hope for the eventual control of Moko only if an integrated approach was made involving the GBCS, the Government of Grenada, Banana Growers and the general public. It was also emphasised that the ultimate control of Moko would rest to a large

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extent on the efforts of the farmers themselves. To this end, a public relations campaign was started, and has been continuing, to keep the general public aware of all aspects of the Moko disease problem including how to recognise the disease, etc. The writer drafted a Plant Protection (Moko Disease) proclamation which has subsequently been passed by the Government of Grenada. The provisions of the proclamation are:-

1. Moko has been declared a notifiable disease, hence occupiers or owners of lands on which Moko may possibly be present are required to look for the disease and report their findings to the Chief Plant Protection Officer who would take all necessary steps to eradicate the disease.

2. Moko infected areas have been placed under a partial quarantine with respect to the movement of planting material of the banana family only.

3. All parts of Moko infected plants and other materials capable of transmitting Moko that have been in contact with Moko infected plants are prohibited from being transported.

4. The planting of suckers of Musa species is prohibited for a period of two years following the eradication of Moko diseased mats, on spot from which the diseased plants were destroyed.

A recommendation was made by the writer for the introduction and testing of the resistant variety Pelipito from Honduras.

CONCLUSIONS

The FAO short-term consultancy of the writer finished in December 1980. Since then the eradication project has been carried on by Mr. James Marrast with occasional professional plant pathological inputs from Mr. E. Ambrose of WINBAN. Discussions with Mr. Ambrose and a report by Mr. Marrast indicate that:-

1. The Roundup technique has continued to be effective and has been improved by Mr. Ambrose.

2. The disease has not spread appreciably outside the original infected zone.

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3. The buffer zone of 15 ft. around diseased plants which I recommended appeared to have been inadequate and this zone has now been increased to 25 ft. The increased buffer zone appears to be adequate.

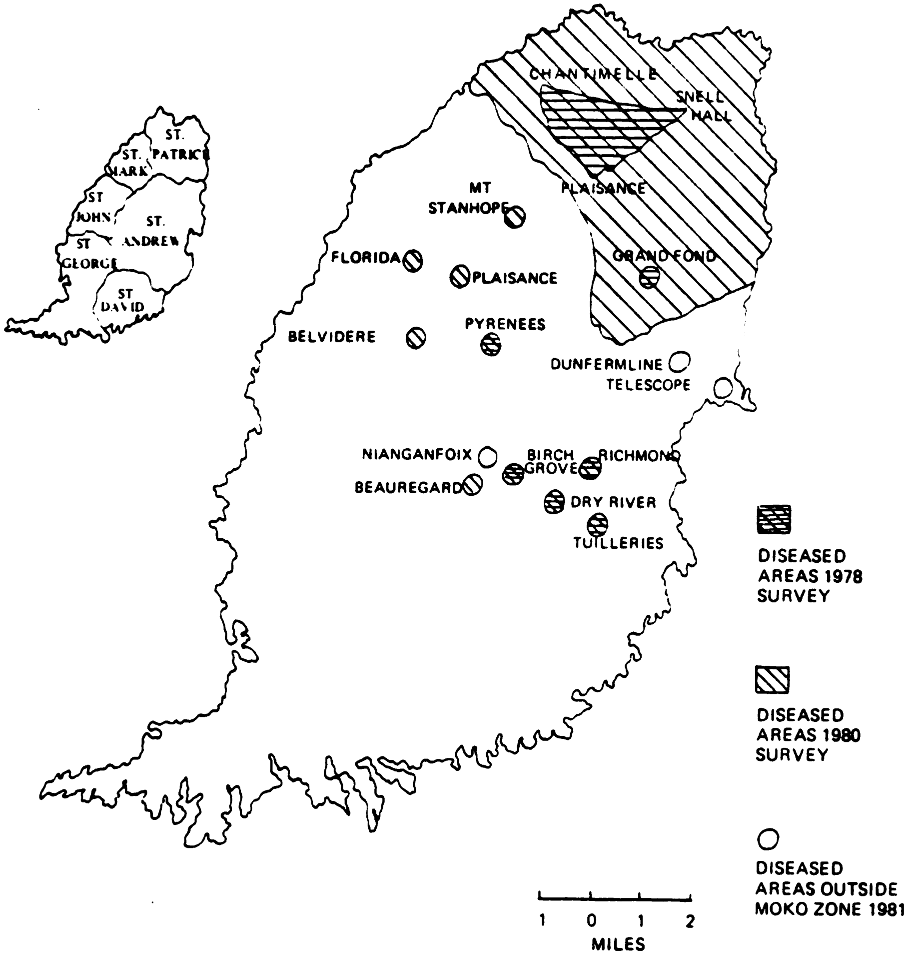

FIG. 1. MOKO DISEASE INCIDENCE JULY 1981, GRENADA

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DISTRICT		HOLDINGS TREATED
ST. ANDREW	– DUNFERMLINE*	5
	PARADISE	2
	SEAMOON	2
	NIANGANFOIX*	1
	TIVOLI	3
	TELESCROPE*	
	PARACLETE	
ST. PATRICK	– ARTHUR SEAT	4
	HERMITAGE	

*Small Pockets of Disease Outside Infected Zone

Others Within Infected Zone

FIG. 2. LIST OF NEW INFECTED AREAS, 1981

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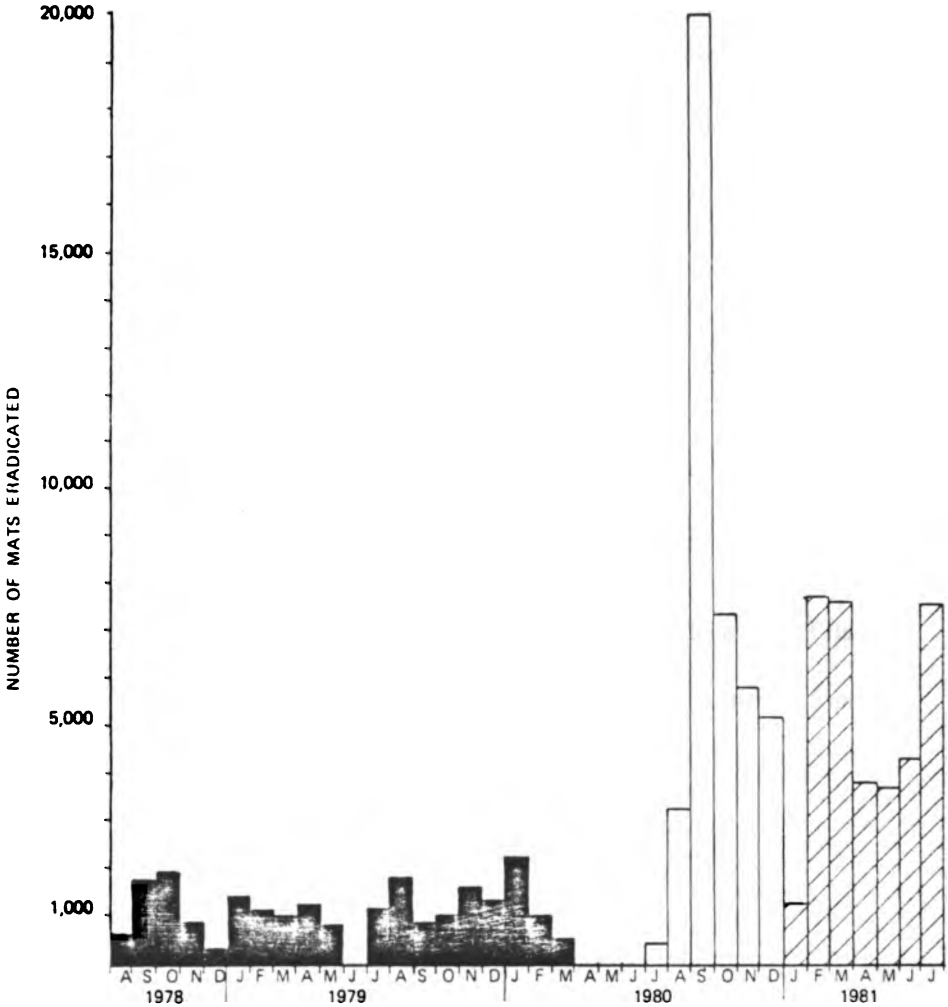

FIG. 3. NUMBER OF MUSA MATS ERADICATED, PER MONTH TO JULY 1981

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PROBLEMS IN THE CONTROL OF MOKO DISEASE *PSUEDOMONAS SOLANACEARUM* OF BANANAS AND PLANTAINS IN GRENADA W.I.

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INTRODUCTION

The banana industry plays a major role in the economies of the Windward Islands of Grenada, St. Vincent, St. Lucia and Dominica. It accounts for about 80 per cent of the export earnings of St. Vincent, St. Lucia and Dominica, and 25-30 per cent in Grenada.

Moko disease caused by the bacterium *Pseudomonas solanacearum* (E.F. Smith) is a very important disease of bananas and plantains. This disease has caused very serious losses in areas where it exist but has inflicted more losses on peasant crops of bananas and plantains than on commercial plantings. The S.R.F. strain of the organism was reported causing losses in bananas and bluggoe in Grenada by Cronshaw and Edmunds (1978). As a result of the threat that this disease poses to the banana industry of Grenada and those of the other Windward Islands, immediate steps had to be taken to eradicate it from the island. The Grenadian authorities were so informed and training sessions have been held for officers of the Ministry of Agriculture and Banana Society to enable them to easily identify Moko disease and not to confuse the symptoms with those of Panama disease or nutritional disorders. An eradication team was established and using the roguing-out method, over 20,000 diseased and buffer zone mats were destroyed over a 22 month period (Small, 1980). The method consisted of uprooting of the diseased or buffer zone mats. After uprooting, using a cutlass, the corms and pseudostems are split into small fragments in the area from which the mat was uprooted and about 600 mls/pseudostem of diesel oil was poured on the banana pieces.

A quick method of eradication was developed by the FAO Consultant, Dr. W. Small in 1980. Over an eight month period over 42,000 diseased and

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buffer zone mats were destroyed. The method consists of injecting 50 ml. of a four per cent solution of Roundup (Glyphosphate) into the diseased or buffer zone mat using a Morton meat pump. (The latter has since been replaced by a "Spot Gun"). Diseased and buffer zone mats were sprayed with an insecticide (Dimethoate) and weeds with Gramoxone.

Many constraints have made this task of eradication a very difficult one in Grenada. There are large numbers of banana growers each with a small area under cultivation (Table 1). Henderson *et. al.* (1975) reported that the majority of banana farmers practice mixed cultivation (Table 2). The farmers traditionally practice subsistence agriculture and depend to a large extent on bananas for a livelihood. The majority of farmers are over 40 years old and about 40 per cent are over 50 years of age (Table 3). The topography of the island is such that over 60 per cent of the growers have their farms on steep hillsides (Table 4). Under such conditions Moko eradication in the island will of necessity be very difficult because the control technology adopted elsewhere is not very applicable in Grenada. Stover (1972) reports from Honduras, Costa Rica and Panama that in a banana zone of 30,000 acres, less than one per cent of the plants are lost yearly because of Moko disease and removal of adjacent healthy plants is an essential part of the control measures. The author went on to say that this low level of loss is maintained only by an expensive system of prevention and control costing nearly US$400,000 annually. "If it were not for the money spent on preventative measures" Stover writes, "losses could increase to over five per cent". Losses in peasant plantings have been high in Central America, Colombia, Venezuela and Peru. Stover further states that "once an insect-transmitted strain reaches a small planting, all plants are infected within a few months".

Early detection and rapid destruction of diseases and buffer zone mats are therefore important in any control programme. This is not very effective in Grenada since financial constraints have not allowed for a specific survey team to carry out frequent visits to the many small farms scattered on the many hill slopes on the island. The eradication team depends to a large extent on the farmers who are relucant to report suspected cases, hoping that the diseased plants will bear marketable bunches. This aspect of loss of revenue is so critical to the subsistence farmer that in many cases he replants bananas soon after his diseased plants have been injected by the eradication team. Extension officers also help in the early detection of the diseased plants but,

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TABLE 1. BANANA ACREAGE DISTRIBUTION, WINDWARD ISLANDS[1]

Banana Acreage	Grenada	St. Vincent	St. Lucia	Dominica
	%	%	%	%
Under 1	20	32	12	16
1 - 3	47	47	52	47
4 - 6	12	8	16	26
7 - 10	8	2	12	6
11 - 20	10	*	4	3
21 - 50	2	*	1	*
50 - 100	–	–	*	*
Over 100	1	*	1	*
Don't know	–	10	3	1

* Indicates less than 0.5%

[1] From Henderson *et al*, 1975

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TABLE 2. DISTRIBUTION OF FARMERS WITH PURE STAND, MIXED STAND AND COMBINED STAND BANANA FIELDS[1]

	Grenada	St. Vincent	St. Lucia	Dominica
	%	%	%	%
Pure Stand	8	49	28	23
Mixed Stand	66	41	64	67
Combined	26	10	8	10

[1] Henderson, 1975

TABLE 3. AGE DISTRIBUTION OF BANANA GROWERS[1]

Age	Grenada	St. Vincent	St. Lucia	Dominica
	%	%	%	%
Under 20	2	x	x	1
21 - 30	14	10	6	16
31 - 40	16	21	28	12
41 - 50	29	25	22	29
51 - 60	12	22	24	21
Over 60	27	21	20	20

x indicates less than 0.5%

[1] Henderson, 1975

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TABLE 4. TOPOGRAPHY OF BANANA LANDS IN THE WINDWARD ISLANDS[1]

Slope Type	Grenada	St. Vincent	St. Lucia	Dominica
	%	%	%	%
Mainly steep slopes	64	52	41	51
Mainly flat	32	41	23	44
Mainly rolling	4	7	31	5
Other	–	–	5	–

[1] Henderson, 1975

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with such a small number of extension officers for the large number of farms, their help is very limited.

Quarantine is an important feature in any Moko control programme. It is very difficult to quarantine diseased areas because of the mixed farming system. The farmer for example must go into the diseased area to harvest his cocoa. Besides, some infected areas may serve as pathways to a neighbour's farm and he will continue to pass through that area. Bananas are used as temporary shade for some young tree crops. When the banana plants are killed the shade plants have to be replaced. The Ministry of Agriculture has recommended that non-host crops e.g. pigeon pea or corn he planted. The problem is how soon should the farmer go into plant. Small (1980) and Ambrose (1980) recommended after a six month fallow. During the six months there will be a loss of revenue to the farmer who depends on his farm for a livelihood. Therefore, the majority of farmers plant these crops about four to six weeks after 'Roundup' treatment. In spite of legislation, farmers move planting material from one farm to another. To prevent this altogether would require considerable effort on the part of the Ministry of Agriculture and Banana Society with already very limited resources. With such large numbers of farms on sloping land and sometimes under poorly drained conditions it is easy for contaminated water to flow from diseased farms to clean ones.

All tools used in Moko infected area must be disinfected in formaldehyde. Some farmers who prune and denavel use cutlasses for thes operations. To reduce the risk of contamination, the Ministry of Agriculture is trying to issue a simple sterilizing pad (pad with foam topped with felt) to be soaked in 10 per cent formaldehyde for disinfection of tools. It is a major problem to provide pads and formaldehyde to over 3,000 farmers and to ascertain that the material is used. Finance is so critical that even the eradication team has on occasion tried to improvise when stocks are low e.g. the use of "Dettol" to substitute for formaldehyde or the dosage of 'Roundup' herbicide injected into the mat is reduced. The farmer should not be involved in the eradication operation yet because of limited resources, the farmer is required to cut back the plants six weeks after they have been injected with 'Roundup' herbicide. In many cases he cuts back much earlier than the recommended time.

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In Moko infected areas of Central America, the buffer zone recommended for the S.F.R. strain is a 15 ft. radius. In Grenada the 15 ft. buffer zone is also recommended (Small, 1980) in addition if more than 15 per cent of the mats are diseased then all bananas and bluggoe plants on the holding should be destroyed. A buffer zone of 15 ft. has proven to be ineffective and the buffer zone has been increased gradually by increments of five feet to 25 ft.A wider buffer zone which would at this stage have been more appropriate is not being used for fear of farmer resistance. The farmer resists since as a subsistence farmer things are viewed in the short term. He sees it as if he is being denied a livelihood. The Ministry of Agriculture pays, with much difficulty EC$3 per mat destroyed at the first visit of the eradication team. Subsequent visits are not being compensated. Unfortunately for the farmer, in some instances the first visit is the one when least plants may be destroyed. (How can the farmer take care of his family without his weekly banana returns?).

There is much research work needed on Moko eradication in Grenada. Several weeds found on infected farms have to be examined to determine whether they are secondary hosts. Nothing is known of the effect of 'Round-up' on the bacterium. This is important since it is necessary to know whether the injected, dying plant or the dead plant after six weeks can still be a source of infection. An important food crop is being destroyed by the disease, therefore substitute food crop varieties have to be introduced. *Musa* varieties resistant to Moko have to be examined. More work is required to increase the efficacy of the 'Roundup' method.

Although much effort has been exercised in carrying the message to the farmer through the radio, newspapers, leaflets, more group talks and slide shows are necessary. Aid organisations are slow in answering the call for assistance in the eradication of Moko in Grenada. The disease was orginally reported in the parish of St. Patrick's but is now being reported also from St. Andrew's, St. Mark's and St. John's. There is a considerable amount of trade amongst the islands of the Windward Islands, with very poor quarantine facilities in these islands the disease poses a great threat to the banana industries and economies of St. Vincent, St. Lucia and Dominica.

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SUMMARY

Moko disease cuased by the bacterium *(Pseudomonas solanacearum)* was discovered to be causing serious losses in bananas and bluggoe in Grenada in 1978. The threat of this disease to the banana industry in Grenada and the Windward Islands in general, necessitated immediate action in trying to contain the disease and prevent its spread.

A quick method of diseased plant eradication was developed by a Food and Agricultural Organization Consultant. Unfortunately, because of the limited time for this consultancy period further field and laboratory investigations were not undertaken. The problems encountered in the eradication programme are outlined and the extent of spread in the island shown.

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REVIEW AND CURRENT STATUS OF MOKO DISEASE RESEARCH IN GUYANA

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INTRODUCTION

Bluggoe plantains (*Musa* ABB triploids) and Cavendish triploid banana (*Musa* AAA) are grown intensively in Guyana totalling some 7,492.5 ha. (18,500 acres) and 1,126.3 ha. (2,781 acres) respectively (Anon, 1980). Plantain, rice and wheat flour which is milled in Guyana from imported wheat are the three major sources of carbohydrates in the diets of the people of the country. From time to time Guyana exports plantains to sister Caribbean countries. Bananas are used mainly as a ripe fruit.

Over the past thirteen years or so, there has been a steady and significant decline in plantain and banana yields. In 1960 yields of plantains averaged 5,727.8 kg. per ha. (4,407 lbs per acre) and in 1973 the figures showed 1,481 kg. per ha. (1,341 lbs per acre) – reduction of 74.1 per cent. Banana production showed the same trend; in 1963 yields were 11,760 kg. per ha (10,500 lbs per acre) whereas the 1973 yields were 4,188.8 kg. per ha. (3,740 lbs per acre) – a reduction of 64.4 per cent (Anon, 1980).

Moko disease is mainly responsible for the depressed production of plantains and bananas. Reduced production has been due to poor yields, death of plants and the abandonment of lands by farmers who have the bitter experience of losses in some cases of the entire crop. Loss estimates show that Moko disease reduces yield by 10-40 per cent (McDonald, unpublished data). The writer has seen instances of entire plantain fields of varying acreage (4-8 hectares) being decimated by the Moko disease.

Research aimed at finding ways to control this disease is imperative if banana and plantain production is to be increased.

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MOKO DISEASE

Bacterial Wilt commonly known as Moko disease *(Pseudomonas solanacearum* E.F. Sm.) is certainly the most destructive disease on plantains mainly the triploid Bluggoe (ABB) and on Cavendish banana (AAA) in Guyana. It is also the oldest disease known on plantains and bananas. The earliest reference to what probably was bacterial wilt of bananas was recorded by Schomburgk in 1840 from the island of Wakenaam in British Guiana (Martyn, 1931). Buddenhagen in 1961 reported that the long standing presence of the disease plus the present observations indicate that the disease is probably idigenous generally in British Guiana (Buddenhagen, 1961). The disease reaches epiphytotic proportions in the riverain areas where plantains and bananas are grown.

The country-wide spread of Moko disease can be traced to the massive movement, especially during the past ten years, of planting materials of all crops including plantains and bananas across the country, the lack of a strict internal quarantine system, and also the indiscriminate use of infected corms with disease.

All control measures tried, both chemical and sanitation, have proven unsatisfactory and the disease continues to plague all areas including new lands cleared for cultivation. Eradication of "Moko" in Guyana and elsewhere has also been undertaken with only partial success (Buddenhagen, 1961; Granada, 1976). Although this disease on plantains and bananas has been known to be present in Guyana since 1840, very little research had been done until most recently.

MOKO DISEASE PROGRAMME IN GUYANA

Because of the high incidence, intensity and prevalence of Moko disease and its wide-spread distribution in the country steps were taken to import the Pelipita cultivar *(Musa* ABB) identified as highly resistant to "Moko" in Central America. In 1975 eighteen corms were imported from the United Fruit Company in Honduras and used in a multiplication programme. A permanent stand of about 300 plants is now being cultivated at the Central Agricultural Station, Mon Repos. These now form an important source of planting materials for testing in selected infected areas throughout the country.

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Three other cultivars also known to be resistant to Moko disease were imported into Guyana from Puerto Rico in 1977: Enano dwarf plantain and banana cultivars, plus Congo and Mari Congo plantains. These are being multiplied also for testing.

In 1979 the Pelipita plantain, a non commercial variety was distributed in several areas where Moko disease of varying intensity has been reported e.g. Ithaca, West Coast Berbice, Parika (Naamyrck 'B' Line and Naamyrck 'C' Line); Parika backdam; Essequibo Coast (Red Lock, Mainstay, Queenstown, Aurora Estate, and Supenaam Creek), West Demerara (Maria's Lodge, Kamuni Creek/Potosi) and most recently in the Essequibo Islands (Wakenaam, Hogg Island and Koriabo Island).

The objectives of the multiplication and distribution exercise are primarily to evaluate Pelipita's resistance under natural conditions, to monitor its growth performance and its adaptability to local conditions, and to extablish and assess the influence of the resistant cultivars used as buffer zones on "Moko" infested soils with special reference to spread, and incidence of the disease.

The Pelipita plantain cultivar has so far shown a high degree of adaptation to local conditions and more importantly resistance to *P. solanacearum*. It grows to a height of 2.80 (m) - 4.66 (m) with a girth of about 57.75 - 65.75 cm. The plantain bunch weighs from 13.6 kg to 29.5 kg. The fingers are stubby with an average length of 12.5 cm. The fruit is seedy with a hard core and not particularly suitable for cooking purposes. The fruit characteristics have proven to be the major disadvantages of Pelipita in terms of replacement of the susceptible and commercially grown Bluggoes. Its acceptability and marketability are very limited. Farmers have already experienced the unmarketability of Pelipita and hence have indicated their reluctance to increase acreage with this plantain cultivar. As mentioned before the idea of introducing Pelipita in the farmers' plot was not in the first instance to grow the cultivar for commercial production but merely to test it.

The Enano dwarf plantain cultivar, one of the other introduced cultivars seems to hold much better prospects than Pelipita for use in commercial production. This cultivar grows to about 1.80 (m) and has a fruit size similar to the Bluggoes approximately 20.0 cm (9 inches) almost twice the length of Pelipita plantain. Its texture and cooking properties are not dissimilar to

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that of the common Bluggoe plantains. Organoleptic tests have shown that there is no difference in taste and palatability of Enano dwarf when compared with the commercial triploid Bluggoes. Preliminary observations have also shown that Enano dwarf is favourably adapted to local conditions but further monitoring needs to be done to confirm its adaptation and to evaluate its resistance under natural conditions. There seems to be two limiting facotors associated with this cultivar being prone to "blow-down" by moderately high winds though a comparatively short plant, and its apparent susceptibility to cigar-end rot *(Trachysphaera fructigena)* a disease which is not known to be of economic importance on Bluggoe plantains and Cavendish triploid bananas in Guyana. In the overall evaluation exercise of this cultivar the above characteristics particularly its resistance to moko disease would be assessed.

The other cultivars are in propagation and under observation.

CURRENT STATUS

In 1979 a planned programme was undertaken in Guyana to:-

1. identify and confirm strain(s) of *Pseudomonas solanacearum* E.F. Sm. race two, the causative agent of Moko disease on plantains and bananas.
2. determine whether biotype differentiation of the bacterial pathogen exists in the various niches where suspectible plantains and bananas are grown.
3. monitoring the growth performance of the exotic resistant cultivars previously mentioned in several habitats infested with 'Moko'.
4. assess the influence of the resistant cultivars used as buffer zones on Moko disease incidence, intensity, and spread in infested cultivations.

If these buffer zones are found to be a successful means to prevent or reduce spread and incidence, this cultural practice can be developed into a strategy to manage this most destructive disease on plantains and bananas for which there is no control measure as yet in commercial fields.

The strain of *Pseudomonas solanacearum* E.F. Sm. race two, was confirmed by Prof. Luis Sequeira, University of Misconsin, Madison as the B

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strain resembling the Amazon type (hypersensitive on tobacco *(Nicotiana tabacum)* and tyrosinase negative) causing fast wilting of banana plants. This finding has now shown that the strain in Guyana differs from that found in Venezuela, Trinidad and most recently in Grenada, and other parts of the Caribbean (Cronshaw and Edmunds, 1980). Buddenhagen, (1961) did allude to the strain of *P. solanacearum* race two, found in then British Guiana as the SFR (small, fluidal, round colonies) insect-transmitted strain. Based on various physiological characteristics Hayward of CMI classified Guyana's isolates into biotype one of the four major biochemical types (Personal communication). French and Sequeira showed that differentiation of strains within race two, can be easily demonstrated on the basis of colony morphology on a tetrazolium (TZC) medium which was also used by Buddenhagen, Sequeira and Kelman *et. al.* to classify several hundred *P. solanacearum* isolates obtained from a wide range of hosts in Central and South America into three races.

The B strain is known to be mechanically transmitted in contrast to the insect-transmitted (SFR) strain. The identification of the strain of *P. solanacearum* race two is important since the methods for control of the pathogen differ in accordance with the particular strain involved and such information is essential in developing a rational programme to prevent further spread of the pathogen (French and Sequeira, 1970). The B strain as identified in Guyana rather than the SFR strain might better allow to test the hypothesis of using buffer zones in infested cultivations with *P. solanacearum.*

Further the introduction of resistant cultivars including the Pelipita plantain might fit well as a cultural practice in Guyana to manage Moko disease in the presence of the B strain, despite some of the poor undesirable characteristics of these cultivars. The first two trials have just been laid down to test the influence of Pelipita resistant cultivar grown among susceptible Bluggoes and triploid bananas in infested fields. Fifty Pelipita plants were strategically placed in a stand of 500 Bluggoe plantains. Observations would be made on the spread and incidence of "Moko" in the two fields.

Biotype differentiation would be soon started using isolates from the various locations in the country to compare their infectivity on solanaceous plants (tomato, egg-plant. pepper) and musaceous hosts (ABB, AAB and AAA).

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SUMMARY

Moko disease is endemic in Guyana and is a major limiting factor to plantain and banana production.

Strain B of *Pseudomonas solanacearum* race two, has been confirmed to be present in Guyana and as the virulent strain causing Moko disease of plantains and bananas. Other workers (Buddenhagen 1961, Cronshaw and Edmunds, 1980) have reported that SFR insect-transmitted strain is found in the rest of the Caribbean. Further studies are to be undertaken to determine if the various isolates of *P. solanacearum* are all similar strains of race two as found above.

The Pelipita cv. *(Musa* ABB) has shown to be resistant to Moko disease and has adapted well to local conditions. Investigations are continuing to test the influence of the resistant Pelipita cultivar and the other identified resistant plantain and banana cultivars: Enano dwarf (plantains and bananas), Congo and Mari Congo when grown as buffer zones on "Moko" incidence and spread in infested cultivations.

Despite the poor cooking properties along with the low marketing potential of the Pelipita cultivar it might still prove to be of a beneficial use in terms of reducing moko disease incidence in infested fields. Enano dwarf plantain has distinctly similar characteristics to the commercially grown Bluggoe plantains, and shows good promise to become a commercially acceptable cultivar resistant to *P. solanacearum.*

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SIGATOKA CONTROL IN BANANAS IN THE CARIBBEAN AND LATIN AMERICA

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INTRODUCTION

The Caribbean Islands and Latin America not only produce about 80 per cent of bananas entering international trade but bananas are an important food for the people. Consequently there is concern about the grave threat posed by Black Sigatoka. The cost of controlling this disease is proving very high for giant corporations like United Brands and is thus likely to result in severe social and economic problems for small producers.

Sigatoka leaf spots in tropical America are caused by two pathogens:-

Mycosphaerella musicola (Yellow Sigatoka)

Mycosphaerella fijiensis var *difformis* (Black Sigatoka)

DIFFERENCES BETWEEN THE TWO DISEASES

The differences between these two diseases are given in Table 1.

There are no differences in morphology of the perithecia and ascospores and so these features cannot be used to distinguish between the two pathogens (Stover, 1980).

DISTRIBUTION

Yellow Sigatoka was first identified in Java in 1902, while Black Leaf Streak *(M fijiensis)* was reported in Fiji in 1964. Black Sigatoka caused by a pathogen closely related to *M. fijiensis* was discovered in Honduras in 1969 (Stover, 1980). The distribution and chronological development of the two pathogens present in this hemisphere are shown in Table 2 (Krigsvold, Woods. 1980; Stover, 1972; Stover, 1980).

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TABLE 1. MORPHOLOGICAL AND CULTURAL DIFFERENCES BETWEEN YELLOW AND BLACK SIGATOKA

	Yellow Sigatoka	Black Sigatoka
Symptoms	Early yellow streaks developing into "line or tip" spotting	Early reddish-brown streaks, later dark brown spots with often distinct pattern along the midvein
Cultures	Grey-brown or black with pink overgrowth	Pink-tinged grey
Conidiophores	In dense sporodochia	Singly or in small groups
Conidia	Cylindric, indistinctly septate	Obclavate, distinctly septate with basal scar
Virulence	Less virulent	More virulent. Greater production of ascospores

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TABLE 2. THE CHRONOLOGICAL DEVELOPMENT OF YELLOW SIGATOKA AND BLACK SIGATOKA

Yellow Sigatoka		Black Sigatoka	
1932	Guadeloupe	1969	Black Sigatoka suspected in Honduras
1933	Suriname and Trinidad	1972	Black Sigatoka confirmed in Honduras
1935	Guyana and Honduras	1973	First Black Sigatoka epiphytotic
1936	Mexico, Belize, Grenada Martinique, Jamaica	1975	Belize
1937	Colombia, Costa Rica Dominican Republic Guatemala, Haiti Nicaragua, Panama St. Vincent	1977	Guatemala
1938	Cuba, Dominica Puerto Rico, St. Lucia	1979	Costa Rica, Nicaragua El Salvador
1944	El Salvador	1980	Panama
1952	Ecuador	1981	Mexico, Colombia

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DISEASE DEVELOPMENT

The life cycle of the Sigatoka pathogens is similar. Spores germinate within two hours on moist leaf surfaces. Germination and infection require humidity at or near saturation and temperatures above 20°C. *M. fijiensis* can grow across the leaf surface to other stomata and does this much more frequently than *M. musicola*. Penetration of stomata occurs in 48-72 hours mostly through lower leaf surface. First streaks appear around the stomata 10-14 days after infection in Black Sigatoka, and about twice as long in Yellow Sigatoka, and about twice as long in Yellow Sigatoka. Finally, symptoms appear as brown spots in line or tip spotting in Yellow Sigatoka and mass infection in Black, sometimes with pronounced spotting on either side of the mid-vein.

VARIETAL SUSCEPTIBILITY

Breeding is a slow process and there are no commercially acceptable cultivars resistant to Sigatoka. Bred tetraploids may have to be substituted for plantains and other cooking bananas, but up to now they have not been found suitable as ripe fruits. The reaction of species of *Musa* to the pathogens is shown in Table 3.

QUARANTINE; EXCLUSION AND ERADICATION

When outbreaks are discovered, the pathogen has usually been there for two years or longer. By this time, it is usually too expensive to eradicate. Costa Rica spent $3 million on an eradication programme without success.

The disease is spread by trucks with trash, movement of rhizomes and suckers, wind-transported ascospores and aircraft and ships.

Natural barriers like oceans or vast unpopulated land areas may exclude the pathogen for a time, as also will official quarantines set up by Governments. Once the disease has entered, the only effect of eradication or internal quarantine would be to delay its movement.

PHYTOSANITATION

Field sanitation is part of an integrated programme for disease control. Badly spotted leaves should be pruned; adjacent fields of unsprayed bananas or plantains may have to be dug up and fields must be free of weeds.

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It is still uncertain what effect leaf pruning has on Sigatoka epidemics, but poor cultural practices and adjacent heavy sources of inoculum increase control costs.

DISEASE FORECASTING

Forecasting systems are not widely used commercially, but a number have been proposed (Stover, 1972), including a crude system based on seasonal rainfall and temperature; Guyot and Cuille humidity and temperature coefficients; Klein's yellow streak count and Meyer-Ganry measurement of evaporation through the Piche evaporimeter.

Because of the seasonal pattern of disease epidemics, spray dosages are increased and there are more cycles during the rainy season. Spray intervals vary from 7-14 days for *M. fijiensis* and 21-40 days for *M. musicola*.

HISTORY OF CHEMICAL CONTROL OF SIGATOKA

The industry has moved from dependence on single products like copper or oil to more sophisticated systems where different products can be used simultaneously, sequentially or in rotation in integrated control programmes.

Stover (1972) divided the history of chemical control of Sigatoka into four periods. Periods V to VII in Table 4 were developed in response to the threat of Black Sigatoka.

To understand the complexities of fungicide use for Sigatoka control the chemicals are differentiated on the basis of their mode of action in Table 5.

Chemical use has evolved from the simpler fungistatics or protectants to the more active systemic fungicides. The more active systemics, because of their single-site inhibitory activity, have led to resistance development in some situation.

Chemicals for Sigatoka control are applied in 18.8-25.0 L total volume per hectare. They are mixed in oil or oil-in-water emulsion except for chlorothalonil.

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TABLE 3. REACTION OF SPECIES OF MUSA TO YELLOW AND BLACK SIGATOKA

	M. musicola	*M. fijiensis* var. *difformis*
Musa AAA	HS	HS
Musa AAB	PR	S
Musa ABB	R	PR
Musa AAAA	R	PR

Varieties are designated by letters indicating ploidy and genome composition with respect to the two parents (A = *Musa acuminata*, B = *M. balbisiana*). HS signifies high susceptibility and PR partial resistance.

TABLE 4. HISTORY OF SIGATOKA CONTROL

I	1934-1958	Bordeaux mixture – the copper era
II	1956	Oil spraying
III	1958	Dithiocarbamate fungicides in oil or oil/water emulsions
IV	1970	Systemic fungicides in oil or oil/water emulsions
V	1978	Chlorothalonil in water
VI	1979	Systemic/protectant fungicides in tank mixtures ("cocktails") in oil/water emulsions
VII	1982	Sterol inhibitors, e.g. imazalil, propiconazole

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TABLE 5. CHEMICALS USED FOR SIGATOKA CONTROL

Fungistatics	Banana spray oil	
Protectants	Manzate® 200 Dithane M-45 Dithane F	a.i. mancozeb
	Calixin	a.i. tridemorph
	Bravo 500 Chlorothalonil 500	a.i. chlorothalonil
Systemic/Protectants	Delsene® Bavistin	a.i. carbendazim = MBC
	Mertect Tecto	a.i. thiabendazole
	Benlate®	a.i. benomyl
	Topsin M Peltis Sigma	a.i. methyl thiophanate
Sterol-Inhibitors	Tilt (= CGA 64250)	a.i. propiconazole
	Trimidal	a.i. nuarimol
	Baycor	a.i. biloxazol
	Fungaflor	a.i. imazalil

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RESISTANCE TO BENZIMIDAZOLES

Resistance occurs when mutant strains in the natural population possess a modified sensitive site (Delp, 1980).

Benzimidazole fungicides act by binding to microtubules of fungi; they inhibit growth and celular division at metaphase. This has been demonstrated in hyphal tip cells of *Fusarium acuminatum.* Exposure to MBC resulted in disappearance of microtubules and altered the distribution of vesicles and mitochondria. These effects result in growth inhibition, swelling and distortion of germ tubes (Howard, Aist, 1980).

Because of the common mode of action of the benzimidazoles, when resistance develops to one, the others lose effectiveness.

Among the banana *Mycosphaerella* pathogens resistant strains selected are not competitive and decline if benzimidazole is withdrawn.

CONTROL STRATEGIES TO COPE WITH RESISTANCE

When a multisite inhibitor, M (e.g., chlorothalonil, mancozeb) is used in all sprays, the probability of resistance is very low to that fungicide, VL (M). If a single site inhibitor, S_1 or S_2, is used alone, the probability is higher, H (S) (5, 7, 2) or for part of the season moderate, M (S).

	Programme	Resistance Probability
1.	M → M → M → M →	VL (M)
2.	$S_1 \to S_1 \to S_1 \to S_1 \to$	H (S_1)
3.	M → M → $S_1 \to S_1 \to$	M (S_1)
4.	M → M → N → N → $S_1 \to S_1 \to$	L (S_1)
5.	M → S_1 → M → S_1 →	M (S_1)
6.	(M+S_1) → M → (M+S_1) → M →	L (S_1)
7.	(S_1+S_2) → (S_1+S_2) →	L (S_2)
		L (S_2)

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M = multisite fungicide, e.g., dithiocarbamates

S_1 = single-site inhibitor, e.g., benomyl, thiabendazole

S_2 = single-site inhibitor which may be prone to resistance, e.g., sterol inhibitors

N = another multisite fungicide.

Resistance to sterol inhibitors is thought to induce changes in fungal membranes which would result in lower fitness. This association of resistance and decreased fitness offers some hope that resistance may be less important than with benzimidazoles but this is not at all certain.

APPLICATION TECHNIQUES

With increasing costs, precision in spraying becomes essential. Many factors need to be considered to ensure that the chemical reaches the infection court. These include proper calibration of mist blowers and aircraft. Applications should be made when spray conditions are optimal in the early morning. For aerial application, swath pattern, flight height and droplet size determine the extent of leaf coverage.

COST OF CONTROL PROGRAMMES

Fungicide input costs are increasing. Average costs of programmes in Central America are given in Table 6. These are programmes in which mixtures are rotated with multisite inhibitors, except for Bravo which may be used alone in water.

CONCLUSION

(a) Producers should actively examine all product options and improve research effort.

(b) Select low cost, high technology programmes. This will require high technology managers.

(c) Impose quarantine regulations against movement by air, ships, people.

(d) Implement integrated disease management.

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(e) Initiate through international and national institutions intensive studies of the biology and life cycles of the pathogens.

TABLE 6. BLACK SIGATOKA CONTROL FUNGICIDE INPUT COSTS

Programme	No. of Applications	Cost/ha/yr
Bravo 500, 3.5L	36	US$ 666.00
Bravo 500, 3.5L + Benlate® OD, 280 G	19 13	438.00
Dithane F, 6L + Benlate® OD, 280 G	19 13	345.00
Manzate® 200 + Benlate® OD, 280 G Oil, 5.0L	19 13	307.00

Costs for Black Sigatoka control may be as high as $1000 per ha for 49-52 cycles per year in Central America. Caribbean producers could not afford these high costs.

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CONTRIBUTED PAPERS

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GROWTH AND YIELD RESPONSE TO DISINFESTING NEGRO YAM *(DIOSCOREA ROTUNDATA)* PLANTING PIECES OF *PRATYLENCHUS COFFEAE* AND PLANTING IN SOIL FREE OF THE NEMATODE

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INTRODUCTION

The involvement of parasitic nematodes in a dry rot of yam *(Dioscorea* spp.) tubers is now clearly established (Coates-Beckford, Brathwaite, 1977 and Nwankiti, Arene, 1978). In Jamaica, this dry rot is called "burn" or "burning" by yam growers. *Pratylenchus coffeae* is the noxious nematode most frequently found in yam tubers affected by the dry rot but *Scutellonema bradys* has been encountered often and *Hoplolaimus* sp. twice.

Symptoms of the dry rot are cracking of the tuber skin and dark necrotic lesions which are corky in texture due to disintegration of the cortex (Coates-Beckford, Brathwaite, 1977 and Hickling, 1976). The appearance of table yams is affected and there is some loss to the housewife when dry-rotted yams have to be peeled peeply on being prepared for cooking. It appears that stem primordia may be destroyed on severely dry-rotted planting material resulting in non-sprouting, hence poor stands in fields planted with such yams (Coates-Beckford, 1978)..Additionally, it seems that plants which grow from "burnt", disintegrating tubers will be unthrifty; poor stands of unthrifty plants would obviously limit quantitative production.

Previous investigations demonstrated that when yam planting pieces affected by the nematode-related dry rot were dipped in hot water and/or certain nematicides, the nematode infestation was reduced and development of the dry rot forestalled (Acosta, Nelia, Ayala, 1976; Coates-Beckford, 1978; Coates-Beckford, Brathwaite, 1977 and Coates-Beckford, Hutton, Jones, 1978).

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The trial being reported was carried out to determine sprouting, growth and yield responses after disinfesting Negro yam *(D. rotundata)* planting material of *P. coffeae* and planting in soil infested with or free of the nematode. This trial was carried out under Project RDJ2 of an IDRC/UWI/Ministry of Agriculture (Jamaica) Root Crops Programme.

MATERIALS AND METHODS

A consignment of Negro yam tubers infested with *P. coffeae* and showing distinct but not advanced symptoms of dry rotting was divided into three batches. One batch was dipped for 30 min. in a 250 ppm. solution of Oxamyl (Methyl *N'N'* dimethyl-N- ((Methylcarbamoyl) oxy)-l-thiooxaminidate), one batch dipped for 40 min in water at 50C and one batch left untreated. Ten days after dipping, the yams were planted in plots free of *P. coffeae* or plots artificially infested by mixing 500 gm of nematode-infested yam skin into the soil in each plot; there was an average of 225 *P. coffeae* per gm. of inoculum. Ten yams were planted per plot; each plot was 3.1 m of a continuous mound. Plant population was roughly 10,900/ha. The six treatments, replicated six times in a Latin Square design, were:-

1. Oxamyl-dipped yams in nematode-free soil.
2. Hot water-dipped yams in nematode-free soil.
3. Undipped yams in nematode-free soil.
4. Oxamyl-dipped yams in *P. coffeae*-infested soil.
5. Hot water-dipped yams in *P. coffeae*-infested soil.
6. Undipped yams in *P. coffeae*-infested soil.

Five and 11 weeks after planting, the yam pieces which had sprouted were counted and the vines measured. At seven months, edible yams were harvested, weighed, then each rated for the dry rot on a 0-4 scale where 0 = no observable dry rotting and one, two, three and four equal one to twenty-five per cent, 26-50 per cent, 51-75 per cent and 76-100 per cent respectively of the tuber's surface affected by the dry rot. At harvest, counts were made of *P. coffeae* in the soil and roots of plants and in the skin of yams from each plot.

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RESULTS

Five weeks after planting, there was no difference between the six treatments in the number of sprouted yams nor in vine length. Al 11 weeks, tubers disinfested in water at 50C for 40 min. showed the highest levels of sprouting and had borne the longest vines; the shortest vines were those growing from undisinfested yam pieces. No treatment caused 100 per cent germination of planting pieces (Table 1).

Plants arising from hot water-treated yam pieces planted in *P. coffeae*-infested soil bore the greatest weights of edible tubers but the observed quantitative yield differences between the six treatments were not statistically significant (Table 2). Tubers borne by plants growing from undisinfested yam pieces planted in *P. coffeae*-infested soil showed the highest levels of dry rotting and the skin of these yams yielded the greatest numbers of *P. coffeae.* The nematode occurred in the roots of plants and in soil from all plots (Table 2).

DISCUSSION

There was no marked improvement in plant growth and development nor in quantitative production when Negro yam planting pieces infested with or disinfested of *P. coffeae* were planted in plots free of the nematode compared to planting in *P. coffeae*-infested plots. Also, there was no lessening of nematode infestation or nematode-related damage (dry rotting) observed on the yam tubers that were produced. There is therefore no suggestion that pre-planting disinfestation of yam fields to reduce populations of noxious nematodes would be beneficial to plant growth and production, especially if *P. coffeae*-infested planting material, even with low levels of infestation, is to be used. However, it is clear that land previously free of *P. coffeae* will become infested with this nematode when infested yam planting material is introduced.

It seems that substantial improvements in sprouting, growth and development and quantitative production are derived from disinfesting yam planting pieces of noxious nematodes. In this trial, yam pieces disinfested in water at 50C for 40 min. showed the highest level of sprouting and bore the longest vines. Overall, disinfestation of yam planting material with Oxamyl or hot water resulted in 22 per cent and 19 per cent greater quantitative yields respectively compared with using undisinfested planting pieces. It appears that thrifty plants are borne by disinfested planting pieces.

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TABLE 1. SPROUTING AND LENGTH OF NEGRO YAM *(DIOSCOREA ROTUNDATA)* VINES GROWING FROM TUBERS DISINFECTED OF *PRATYLENCHUS COFFEAE* BY NEMATICIDE OR HOT WATER DIPS THEN PLANTED IN PLOTS INFESTED WITH OR FREE OF THE NEMATODE

Treatments	5 weeks after planting		11 weeks after planting	
	Sprouted tubers (%)	Average length of vines (m)	Sprouted tubers (%)	Average length of vines (m)
Oxamyl-dipped[1] yams in uninfested soil	10	0.44	80	4.0
Hot water-dipped[2] yams in uninfested soil	7	0.24	86	4.0
Untreated yams in uninfested soil	7	0.28	77	3.7
Oxamyl-dipped[1] yams in infested soil[3]	12	0.22	77	3.8
Hot water-dipped[2] yams in infested soil[3]	12	0.26	85	3.8
Untreated yams in infested soil[3]	13	0.21	82	3.6

[1] Yams dipped for 30 min. in a 2500 ppm Oxamyl solution.

[2] Yams dipped for 40 min. in water at 50C.

[3] Five hundred gm of *P. coffeae*-infested yam skin (average - 225/gm) mixed into soil in plot of 3.1m of a continuous mound

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TABLE 2. QUALITY AND EXTENT OF DRY ROTTING OF NEGRO YAM *(DIOSCOREA ROTUNDATA)* TUBERS HARVESTED SEVEN MONTHS AFTER YAM PIECES DISINFESTED OF *PRATYLENCHUS COFFEAE* WERE PLANTED IN PLOTS INFESTED WITH OR FREE OF THE NEMATODE AND LEVELS OF *P. COFFEAE* IN SOIL, PLANT ROOTS AND TUBERS AT HARVEST

Treatments	Wt. of tubers/ plot of 10 plants (kg)	Returns/ planted piece of 0.48 kg (kg)	Levels of burning on tubers[4]	Counts of *P. coffeae* per		
				100 cc soil	gm root	gm tuber skin
Oxamyl-dipped[1] yams in unifested soil	13.09	2.73	2.31	4	62	4
Hot water-dipped[2] yams in uninfested soil	15.17	3.16	2.22	5	31	10
Untreated yams in uninfested soil	11.16	2.33	2.07	12	10	18
Oxamyl-dipped[1] yams in infested soil[3]	14.98	3.12	2.11	19	86	6
Hot water-dipped[2] yams in infested soil[3]	12.12	2.53	2.19	6	40	9
Untreated yams in infested soil[3]	11.70	2.44	2.51	5	15	49

[1] Yams dipped for 30 min. in a 2500 ppm Oxamyl solution.

[2] Yams dipped for 40 min. in water at 50C.

[3] Five hundred gm of *P. coffeae* -infested yam skin (avg. 225/gm) mixed into soil in plot of 3.1m of a continuous mound.

[4] Yams rated for dry rotting on a 0-4 scale where 0 = no observable dry rotting, 1 = 1-25%, 2 = 26-50%, 3 = 51-75% and 4 = 76-100% of the yam's surface affected by the dry rot.

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To date, no chemical and/or hot water treatment which still leaves yam planting pieces viable has been shown to bring about complete eradication of noxious nematodes infesting the yams. It appears that so long as the planting material is infested, regardless of the nematode levels, tubers harvested from the resultant plants will be infested with the particular nematode and show nematode-related damage (dry rotting). This has been observed in this and other trials. Evidently, the only way to grow yams which are free of nematode infestation and related damage is to plant nematode-free yam pieces in uninfested soil. However, this would appear to be difficult to achieve in Jamaica where yams are always infested with noxious nematodes and where the nematodes associated with dry rotting of yams, expecially *P. coffeae* are ubiquitious.

SUMMARY

Pratylenchus coffeae is the phytoparasitic nematode most frequently found infesting yam *(Dioscorea* spp.) tubers affected by a dry rot called "Burn" or "burning" in Jamaica; *Scutellonema bradys* has been encountered often and *Hoplolaimus* spp. twice. It appears that the dry rot injures or destroys primordia on yam planting material resulting in unthrifty plants or non-sprouted planting pieces hence poor stands in the field. Negro yam *(D. rotundata)* planting pieces were disinfested of *P. coffeae* by dipping in water at 50C for 40 min. or for 30 min. in a 2,500 ppm. Oxamyl solution or left undisinfested. The yam pieces were planted in plots artifically infested with or free of *P. coffeae.* After five and 11 weeks, there was no significant difference between treatments in numbers of sprouted yam pieces. At 11 weeks, vines borne by undisinfested planting pieces in *P. coffeae*-infested plots were shortest while the tallest vines had grown from disinfested yam pieces in *P. coffeae* free plots. Overall, plots planted with yam pieces disinfested by Oxamyl or hot water produced 22 per cent and 19 per cent greater quantitative yields of tubers respectively than those with undisinfested pieces. Tubers borne in *P. coffeae*-infested plots planted with undisinfested yam pieces showed highest levels of the nematode-related dry rot.

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EFFECT OF INFECTION WITH *PRATYLENCHUS COFFEAE* ON GROWTH AND YIELD OF YELLOW YAM *(DIOSCOREA CAYENENSIS)*

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Ministry of Agriculture, Hope Gardens, Jamaica and
The Inter-American Institute for Cooperation on Agriculture
as part of the "Hillside Farming Development Project".

INTRODUCTION

Yam *(Dioscorea* spp.) tubers in Jamaica are affected by a dry rot, called "burning" or "burn", with which parasitic nematodes *(Pratylenchus coffeae, Scutellonema bradys* and *Hoplolaimus* sp.) are associated. The dry rot is characterised by cracking in the skin underlaid by a corky rot in the storage tissues (Coates-Beckford and Brathwaite, 1977). No yellow yam *(D. cayenesis)* tuber free of *P. coffeae* has yet been found by the senior authors; to date, this is the only noxious nematode found infesting tubers of this cultivar. It seems that the dry rot, which spreads over the tuber's surface and progresses deeper into the yam tissues as tubers or parts of tubers are stored prior to being planted, damages or destroys stem and root primordia. Thus, plants arising from severely dry-rotted heads might be unthrifty or such heads might not sprout resulting in poor stands. In previous trials, disinfesting yam planting material by hot water or nematicide dips resulted in suppression of noxious nematodes and development of the dry rot, higher and earlier germination and vines that were more vigorous compared with undisinfested heads. In trials using yellow yams, significantly more Oxamyl-disinfested heads sprouted than undisinfested heads (Coates-Beckford, 1978 and Hutton: In Press).

With certain crops (plantain, banana, some ornamentals, etc.), post-plant nematicide treatments are a standard feature of nematode control. In a trial with yellow yams, tubers from plots treated with a nematicide twice during the season were less affected by the nematode-related dry rot than tubers from untreated plots (Hutton: In Press). If indeed the dry root damages/destroys stem and root primordia, then any treatment which causes tubers or parts of tubers used as planting material to have less of the dry rot would be beneficial.

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This trial was carried out to determine:-

(i) the critical levels of dry rotting of yellow yam heads, i.e., the level at which significant damage/destruction of stem and root primordia might occur and the level of dry rotting which therefore is acceptable in planting material,

(ii) the benefits of disinfesting heads having the extremes of dry rotting (light or heavy) of noxious nematodes, *Pratylenchus coffeae* in this case, and

(iii) the effects of post-plant nematicide treatments in reducing the levels of dry rotting on harvested tubers as well as on quantitative yields.

MATERIALS AND METHODS

Light and severely dry rotted yellow yam heads were selected from a batch of recently-harvested tubers. The first group consisted of heads with less than 15 per cent of the surface having symptoms of the dry rot with depth of any dry rot ranging from one to two mm (avg. 1.5 mm). The second group consisted of heads with more than 66 per cent of the surface having the dry rot with depth of the rot ranging from four to 11.5 mm (avg. 6.6 mm). One-half of the yams from each group were dipped for 40 min. in a 1,500 ppm. solution of Oxamyl (Methyl N'N'-dimethyl-N- ((methylcarbamoyl)oxy)-1-thiooxamimidate). Three days later, the heads were planted 0.67 m apart on continuous contour mounds spaced 1.5 m apart giving a crop density of 10,000 plants/ha. The site had been cropped to yellow yams continuously for at least 10 years. Eleven, 22 and 33 weeks after planting, plots were treated with Oxamyl G (12.2 kg a.i./ha.), or Ethoprop G ()-Ethyl S, S-dipropyl phosphorodithioate) (13.9 kg a.i./ha.), or left untreated giving 12 treatments *viz*:-

1. Heavily dry-rotted heads dipped in Oxamyl; Ethoprop applied post-planting.
2. Heavily dry-rotted heads dipped in Oxamyl; Oxamyl applied post-planting.
3. Heavily dry-rotted heads dipped in Oxamyl; no post-plant treatment.
4. Heavily dry-rotted heads untreated; Ethoprop applied post-planting.
5. Heavily dry-rotted heads untreated; Oxamyl applied post-planting.
6. Heavily dry-rotted heads untreated; no post-planting treatment.

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7. Lightly dry-rotted heads dipped in Oxamyl; Ethoprop applied post-planting.
8. Lightly dry-rotted heads dipped in Oxamyl; Oxamyl applied post-planting.
9. Lightly dry-rotted heads dipped in Oxamyl; no post-plant treatment.
10. Lightly dry-rotted heads untreated; Ethoprop applied post-planting.
11. Lightly dry-rotted heads untreated; Oxamyl applied post-planting.
12. Lightly dry-rotted heads untreated; no post-plant treatment.

The 12 treatments were replicated thrice using a randomised complete block design. The nematicide applied after planting were sprinkled onto the ground around plants then worked in lightly.

Six, seven, nine, 11 and 22 weeks after planting, sprouted heads were counted. At six, nine and 11 weeks, vine height was measured. The width of leaves was taken at six (first node) and 17 weeks (second node). Samples of soil and root material were taken at 39 weeks for estimating levels of *P. coffeae.*

At harvest (47 weeks), *P. coffeae* in soil and tuber skin (peeling) was again counted. Each tuber was rated for the nematode-related dry rot on a one to five scale where one, two, three, four and five signified that one to 20 per cent, 21-40 per cent, 41-60 per cent, 61-80 per cent and 81-100 per cent respectively of the tuber's surface was affected by the dry rot. Gross tuber weight, weight of heads and weight of marketable yams produced by each plant were recorded.

This trial was carried out at Olive River, an adjunct to the Allsides Pilot Development Project, on a site farmed co-operatively by the Inter-American Institute for Co-operation on Agriculture and the Ministry of Agriculture, Jamaica. Plots were fertilized with a mixture of $N:P_2O_5:K_2O$ (12:24:12) at the rate of 1,460 kg/ha, split in two applications at six and 14 weeks from sowing. Economy of staking was achieved by using one six to eight meter bamboo stake for every four plants.

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RESULTS

Heavily dry rotted heads which remained undisinfested of *P. coffeae* took longer to sprout compared with heavily dry-rotted disinfested heads and lightly dry-rotted disinfested or undisinfested heads. Six, seven, nine and 11 weeks after planting, significantly more of the lightly dry rotted disinfested or undisinfested heads had sprouted compared with heavily dry-rotted undisinfested heads. Sprouting of heavily dry rotted heads dipped in Oxamyl occurred significantly earlier than heavily dry rotted undisinfested heads. Overall, lightly dry rotted heads which remained undipped sprouted earliest (Table 1). Plants arising from heavily dry rotted undisinfested heads were least vigorous as measured by vine height and leaf size (Table 1).

At 39 weeks from planting, highest numbers of *P. coffeae* were found in soil and root samples from plots which received no post-plant nematicide treatment. However, soil and root samples from plots in which undisinfested, heavily dry rotted heads were planted and which received no post-plant nematicide treatment contained comparatively low levels of the nematode. Treatments with Ethoprop of Oxamyl suppressed *P. coffeae* but roots of plants from the Ethoprop-treated plots harboured lowest levels of the nematode at 39 weeks. However, at harvest there was no difference in the levels of *P. coffeae* in soil nor skin of tubers irrespective of whether plots were treated with a nematicide or not (Table 2).

There was no evidence that the post-plant nematicide treatments influenced gross tuber production but Oxamyl treatments resulted in significant reductions in the dry rot ("burning") observed on harvest tubers (Table 3). However, planting lightly dry-rotted heads or heads disinfested of *P. coffeae* clearly influenced gross tuber yields. There was significantly less bearing among plants from heavily dry-rotted undisinfested heads compared with those from lightly dry-rotted undisinfested heads or disinfested heads. Lowest tuber yields were observed in plots planted with heavily dry-rotted undisinfested heads. Highest yields were produced by plants arising from lightly dry-rotted disinfested heads (Table 3).

DISCUSSION

Results from this trial indicate that as the nematode-related dry rotting on yellow yam heads becomes more severe, the more unfit these heads become

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TABLE 1. EARLINESS OF SPROUTING OF YELLOW YAM *(DIOSCOREA CAYENENSIS)* PLANTING MATERIAL (HEADS) AND GROWTH AND DEVELOPMENT OF PLANTS IN A TRIAL TO INVESTIGATE *INTER ALIA*, CRITICAL LEVELS OF DRY ROTTING AND THE BENEFITS OF DISINFESTING THE HEADS OF *PRATYLENCHUS COFFEAE*

Treatments	Sprouting after planting (%)					Plant height (m)			Leaf width (cm)	
	6 wk	7 wk	9 wk	11 wk	22 wk	6 wk	9 wk	11 wk	6 wk 1st node	17 wk 2nd node
Heavily dry-rotted[a] heads disinfested with Oxamyl[c]	20	43	72	91	99	0.42	1.23	1.90	6.7	13.5
Heavily dry-rotted[a] undisinfested heads	15	27	64	77	92	0.38	0.90	1.68	6.4	12.9
Lightly dry-rotted[b] heads disinfested with Oxamyl[c]	35	51	88	97	99	0.29	1.12	1.99	6.6	13.6
Lightly dry-rotted[b] undisinfested heads	40	58	90	96	99	0.38	1.32	2.22	6.9	13.5
LSD 5%	9.0	10.7	8.3	9.4	–	–	–	0.37	–	0.56

[a] More than 66% of surface of head affected by the dry rot and depth of rot 4-11.5mm (avg. 6.6mm)

[b] Less than 15% of surface of head affected by the dry rot and depth of rot 1-2mm (avg. 1.5mm)

[c] Dipped for 40 min. in a 1500 ppm solution

TABLE 2. NUMBERS OF *PRATYLENCHUS COFFEAE* FOUND IN SOIL ABOUT, ROOTS OF AND SKIN OF TUBERS BORNE BY YELLOW YAM *(DIOSCOREA CAYENENSIS)* PLANTS IN A TRIAL INVESTIGATING CRITICAL LEVELS OF DRY ROTTING OF PLANTING MATERIAL (HEADS), THE BENEFITS OF DISINFESTING THE HEADS AND THE USE OF POST-PLANT NEMATICIDE TREATMENTS

Treatments		Numbers of *P. coffeae*			
		At 39 weeks		At harvest (47 wk)	
Before planting	After planting	Per 100ml soil	Per 10gm root	Per 100ml soil	Per 10gm tuber skin
Heavily dry-rotted[a] heads disinfested with Oxamyl[c]	Ethoprop[d]	17	20	19	70
	Oxamyl[e]	3	160	21	40
	None	90	1270	20	110
Heavily dry-rotted[a] undisinfested heads	Ethoprop[d]	3	30	8	50
	Oxamyl[e]	1	200	9	60
	None	20	290	23	80
Lightly dry-rotted Lightly dry-rotted[b] heads disinfested with Oxamyl[c]	Ethoprop[d]	3	30	25	80
	Oxamyl[e]	5	340	2	40
	None	73	2250.	26	90
Lightly dry-rotted[b] undisinfested heads	Ethoprop[d]	3	90	5	70
	Oxamyl[e]	3	330	27	100
	None	130	860	29	80
LSD 5%		62	795	–	–

[a] More than 66% of surface area of head affected by the dry rot and depth of rot 4-11.5mm (avg. 6.6mm)

[b] Less than 15% of surface area of head affected by the dry rot and depth of rot 1-2mm (avg. 1.5mm)

[c] Dipped for 40 min. in a 1500 ppm solution

[d] 13.9 kg ai/ha of Ethoprop 10G at 11, 22 and 33 weeks

[e] 12.2 kg ai/ha of Oxamyl 10G at 11, 22 and 33 weeks

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TABLE 3. QUALITATIVE AND GROSS TUBER YIELDS OF YELLOW YAM *(DIOSCOREA CAYENENSIS)* IN A TRIAL TO INVESTIGATE CRITICAL LEVELS OF DRY ROTTING OF PLANTING MATERIAL (HEADS) AND THE BENEFITS OF DISINFESTING THE HEADS OF *PRATYLENCHUS COFFEAE* AT PLANTING FOLLOWED BY POST-PLANT NEMATICIDE TREATMENTS

Treatments		Bearing plants	Level of dry rotting[f] on tubers	Tuber yields per plot planted with 10 heads (kg)		
Before planting	After planting	(%)		Total	Heads	Marketable
Heavily dry-rotted[a] heads disinfested with Oxamyl[c]	Ethoprop[d]	94	3.2	40.93	11.93	25.27
	Oxamyl[e]	94	2.9	41.27	10.83	25.53
	None	94	3.7	41.97	11.80	21.33
Heavily dry rotted[a] undisinfested heads	Ethoprop[d]	86	3.5	37.60	9.60	21.73
	Oxamyl[e]	78	2.6	29.30	9.03	17.57
	None	81	3.4	33.47	10.93	13.60
Lightly dry-rotted[b] heads disinfested with Oxamyl[c]	Ethoprop[d]	94	3.0	38.70	11.10	24.90
	Oxamyl[e]	100	3.1	50.33	12.90	30.37
	None	100	3.3	46.10	12.13	27.80
Lightly dry rotted[b] undisinfested heads	Ethoprop[d]	90	3.7	35.60	11.47	21.80
	Oxamyl[e]	94	3.5	41.97	13.00	26.00
	None	94	4.3	37.47	12.17	20.40
LSD 5%		9.4	0.7	10.40	–	–

[a] More than 66% of surface of head affected by the dry rot and depth of rot 4-11.5mm (avg. 6.6mm)

[b] Less than 15% of surface of head affected by the dry rot and depth of rot 1-2mm (avg. 1.5mm)

[c] Dipped for 40 min. in a 1500 ppm solution

[d] 13.9kg ai/ha of Ethoprop 10G at 11, 22 and 33 weeks

[e] 12.2kg ai/ha of Oxamyl 10G at 11, 22 and 33 weeks

[f] Dry-rotting rated on a 1-5 scale where 1,2,3,4 and 5 = 1-20%, 21-40%, 41-60%, 61-80% and 80-100%, respectively at the head's surface having the dry rot

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as planting material. Degras and Mathurin (1980) reported that as tubers of certain *Dioscorea* spp. mature, undifferentiated cellular blocks appear in the deep cortical layers. These cellular blocks are later involved in morphogenesis generally according to a gradient in favour of the stem end of the tuber. It appears that as the dry rot spreads and penetrates deeper into the yam head, these cellular blocks are injured or destroyed. The ability of badly affected heads to produce vigorous plants would gradually diminish and eventually when all primordia are destroyed, such heads would not germinate. It seems that when yam heads are planted, soil temperature and moisture favour rapid development of populations of noxious nematodes and of the nematode-related dry rot and as a consequence, primordia are injured or destroyed. Disinfestation of yam planting material has been shown to suppress populations of invading nematodes and development of the dry rot and disinfested planting material produced vigorous plants (Hutton: In Press).

Results of this trial demonstrate that there are advantages to using planting material with little evidence of the dry rot; disinfestation provides further benefits, especially increased tuber yields. In the case of heads severely affected by the dry rot, disinfestation results in earlier and more sprouting, increased vigour of plants and increased quantitative yields. It appears that poor stands and more non-tuber bearing plants were the important factors related to decreased quantitative yields when heavily dry-rotted undisinfested heads were planted compared with lightly dry-rotted heads or disinfested heads.

Post-plant applications of Oxamyl and Ethoprop suppressed levels of *P. coffeae* in the soil and roots of the yellow yam plants. Applications of Oxamyl resulted in significantly less dry rotting of harvested tubers thus enhancing the suitability of these tubers as planting material.

The authors recommended that the Ministry of Agriculture or a designated agency establish pilot schemes in the major yam-growing areas for the purpose of disinfesting yam planting material, preferably with Oxamyl. We further recommend the establishment of large-scale field trials designed to assess the economic benefits of disinfested planting material. These actions followed by the deployment of an agency to provide "clean" yam planting material are seen as imperative if increased production and productivity of yams are to be realised in Jamaica.

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SUMMARY

Several noxious nematodes are associated with yams *(Dioscorea* spp.) in Jamaica but *Pratylenchus coffeae* is the only one found infesting yellow yams *(D. cayenensis)* tubers affected by a dry rot called "burning". There was earlier and significantly more sprouting of lightly or heavily dry-rotted yellow yam heads (planting material) which were dipped for 40 min. in a 1,500 ppm Oxamyl solution or lightly dry-rotted undisinfested heads and plants arising from them developed more vigorously (as measured by vine height and leaf size) compared with heavily dry-rotted undisinfested heads. There was significantly less bearing plants in plots planted with the heavily dry-rotted undisinfested heads; greatest gross weights of tubers and of marketable yams were borne in plots planted with lightly or heavily dry-rotted disinfested heads and lightly dry-rotted undisinfested heads. Oxamyl or Ethoprop applied 11, 22 and 33 weeks after planting suppressed populations of *P. coffeae* in soil and roots at 39 weeks but did not influence quantitative production; tubers from Oxamyl-treated plots showed significantly less of the dry rot. The dry rot appears to damage or destroy stem and root primordia resulting in badly affected planting material not sprouting or plants not being vigorous. Conditions favouring rapid development of the dry rot seem to prevail after heads are planted. Disinfestation suppresses populations of the nematodes associated with the dry rot and development of the rot itself. Results suggest that only those yellow yam heads with the least evidence of the dry rot or disinfested heads should be planted. It is recommended that an agency be established to see to the disinfestation of yam planting material in the first instance and eventually be responsible for providing "clean" planting material.

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A SURVEY OF THE VIRUS DISEASES OF ECONOMIC PLANTS IN MONTSERRAT

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INTRODUCTION

Between November 1979 and February 1981, a survey of the cultivated plants was carried out in order to identify the sap-transmissible viruses endemic in Montserrat. Identifications were based mainly on host range, symptomatology and serodiagnostic assays.

In 1980, Thomas reported an outbreak of potato virus Y on hot and sweet peppers in Montserrat which was the only positive identification of virus diseases in this island so far. This report deals with other findings of the survey.

MATERIALS AND METHODS

Young leaves of the plants that showed virus-like symptoms were homogenized in 0.03 M Phosphate buffer at pH7 except for pepper where the leaves were homogenized in 0.03 M Phosphate buffer pH7 containing 0.1 per cent Sodium Diethl-dithiocarbamate (Na DIECA) in 1:1 ratio (Lana and Agrios, 1974). The homogenate from the different samples collected were mechanically inoculated to a wide range of indicator host plants in the greenhouse.

The samples collected from the cucurbits were inoculated to cucumber *(Cucumis sativa* 1), squash *(Cucurbita maxima),* pumpkin *(Cucurbita pepo), Nicotiana glutinosa* 1., and *Chenopodium amaranticolor* Coste and Reyn.

Samples from the family *Leguminosae* were inoculated to *Crotalaria spectabilis* 1., *Vicia Faba,* cowpea *(Vigna unguiculata), C. quinoa* Wild., and *C. amaranticolor* Coste and Reyn. Those from the family Solanaceae, were inoculated to tobacco *N. tabacum* and *N. gluttinosa,* pepper *Capsicum annum,*

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Comphrena globosa Rybd., *Physalis floridana.* Samples taken from the sweet potato were inoculated to tomato *Lycopersicon esculentum, N. glutinosa, N. tabacum, G. globosa* and *C. annum.* The sap from the cotton samples were inoculated to all the above named indicator plants. Leaf dip preparation of some of the indicator assay plants that developed systemic infection were taken for electron microscopy. Sap was then extracted and used in agar gell double diffusion or tube precipitin tests to identify the viruses.

SERODIAGNOSIS

The viruses recovered from the leguminous plants were tested against antisera to cowpea mosaic, broad bean mosaic, southern bean mosaic, broad bean mottle, broad bean true mosaic and cucumber mosaic viruses. Those recovered from the Cucurbitaeae were tested against squash mosaic, cucumber mosaic and water melon mosaic antisera.

The viruses from the Solanaceous plants that produced systemic reactions were tested against PVX, PVY, CMV and TMV antisera. The sap from the systemically infected *N. glutinosa* were treated with dithiocarbamate heated to 40°C, then clarified by low speed centrifugation in order to prevent the occurrence of nonspecific reactions. The sap recovered from the convulvulaceous plant was tested against the following antisera:- TMV, PVX, PVY, CMV, and sweet potato mosaic viruses.

RESULTS AND DISCUSSION

The sap-transmissible viruses that were identified on the cultivated plants throughout the island are shown in Table 1. The viruses from the cantaloupe and pumpkin produced symptoms in cucumber and pumpkin indicator plants and reacted positively to antiserum to squash mosaic virus. Viruses from water-melon and squash, cucumber and pumkin produced symptoms in cucumber, *C. amaranticolor, N. glutinosa* and squash indicator plants also produced reactions against CMV antiserum. There was evidence of complex infections of the pumpkin and squash by the squash mosaic virus and the cucumber mosaic virus. Watermelon mosaic virus was identified on pumpkin and water-melon.

The viruses from the red kidney bean and the cowpea in the central districts produced local lesions in cowpea and reacted serologically to cowpea

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TABLE 1. SAP TRANSMISSIBLE VIRUSES IDENTIFIED IN CULTIVATED CROPS IN MONTSERRAT

Host	Locality	Viruses Identified
Solanaceae		
Hot Pepper	Island wide	Potato virus Y
Sweet Pepper	Groves	Potato virus Y
Potato	Farrels	None
Tomato	Richmond Hill	Potato virus Y
Tomato	Dagenham	Tobacco mosaic virus
Egg Plant	Groves	None
Fabaceae		
Red Kidney Beans	Richmond Hill	Bean yellow mosaic
Red Kidney Beans	Farrels	Cow pea mosaic
Pigeon Pea	Groves	None
String Beans	Lees	Bean yellow mosaic
Cow Pea	Lees	Bean yellow mosaic
Broad Bean (Jamaica Bean)	Ricmond Hill	Cow pea mosaic
Peanuts	South	None

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TABLE 1 (Cont'd)

Host	Locality	Virus Identified
Cucurbitaceae		
Water Melon	South	Water Melon mosaic
Water Melon	Richmond Hill	Cucumber mosaic
Cucumber	Plymouth	Cucumber mosaic
Cantaloupe	Richmond Hill	Squash mosaic
Squash	Groves	Squash mosaic
Pumpkin	Richmond Hill	Water Melon mosaic
Pumpkin	Groves	Squash mosaic
		Cucumber mosaic
Squash	Groves	Squash mosaic
		Cucumber mosaic
Convulvulaceae		
Sweet Potato	Stratheam	Sweet potato mosaic Y
Malvaceae		
Sea Island Cotton	Whites	None

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mosaic virus. The string bean and red kidney bean taken from another area in the central district reacted systemically in *Crotalaria spectabilis* and *C. quinoa.* This suggested the presence of BYMV which was substantiated by positive serological reaction to BYMV antiserum.

Virus from sweet and hot peppers, and tomato induced local lesion on *Physalis floridana*, and systemic reaction in *N. glutinosa.* Agar double diffusion tests using the sap from infected *N. glutinosa* gave a positive reaction to antiserum against PVY. Tomato collected from Dagenham and Richmond Hill when inoculated to *N. glutinosa*, produced local lesion within two days indicating the presence of TMV. This supports the report by Grill *et. al.* (1972), that tomato mosaic virus is in. The same *N. glutinosa* plants that developed local lesion after inoculation with sap from tomato showed systemic reaction after two weeks which were confirmed by PVY serology. The tomato plants that showed severe symptoms in the fields seemed to have a complex infection by TMV and PVY.

Some of these viruses were previously identified mainly on the basis of field symptomatology and are now confirmed by serology. The sweet potato mosaic symptoms could not be confirmed by serology nor host range symptomatology, because of the futility in my efforts to transmit the virus mechanically and the non availability of antiserum to sweet potato mosaic virus. The survey revealed that there was a 30 per cent level of infection of PVY on peppers (Thomas 1980) and that some fields had as high as 74 per cent infections. Although this virus cause a very destructive disease on potatoes in many Caribbean countries (Phelps and Haque, 1973), the survey showed that the potatoes in Montserrat were free from the disease. No viruses were recovered from sea island cotton.

SUMMARY

A survey of cultivated plants throughout Montserrat resulted in the identification of a number of viruses. The viruses identified were:- Squash mosaic virus in contaloupe, pumpkin and squash; potato virus Y (PVY) in peppers and tomato; bean yellow mosaic and cowpea mosaic viruses in red kidney beans and string beans and cowpea mosaic viruses in cowpea and broad bean. Other viruses that were previously identified on the basis of field sympto-

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matology were confirmed by host range and serology. There were no viruses recovered from sea island cotton sweet potato. The sap extracted from indicator plants that showed systemic symptoms was used in serodiagnostic assays for virus identification. This is the first attempt to positively identify the viruses of economic plants in Montserrat.

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INTRODUCTION OF EXOTIC PARASITES FOR CONTROL OF *SPODOPTERA FRUGIPERDA* IN TRINIDAD, THE EASTERN CARIBBEAN AND LATIN AMERICA

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INTRODUCTION

Spodoptera frugiperda (J.E. Smith) commonly known as the fall army-worm or corn leaf worm is polyphagous attacking several crops as well as non-cultivated plants in the new world tropics and subtropics. Luginbill (1928) while listing more than 60 species of host plants stated that it has a decided preference for graminaceous plants such as corn, sorghum, rice, sugarcane and natural and cultivated pasture grasses. Corn *(Zea mays* L.), cultivated as a subsistence crop in the Caribbean territories, is staple in several of the Latin American countries. Because of its importance as a source of oil and fats, peanut production is also expanding in these regions. *S. frugiperda* is frequently the most important pest of both these crops. Attack commences shortly after germination and if repeated adversely affects yields.

In the tropics, the pest reproduces successfully throughout the year especially during the wet months when natural pastures and graminaceous plants abound. Although some research has been done on the bionomics of *S. frugiperda* in the Caribbean region (Labrador, 1967), further investigations need to be undertaken to develop a pest management system under neotropical conditions. In order to control this pest, farmers often resort to the use of chemical pesticides but often there is a general lack of information on techniques best suited to the developmental stage and growth characteristics of the particular crop. In many instances, the use of chemical control is uneconomic and of limited success because of the short life cycle and overlapping generations of the pest and the short residual life of most of the more effective

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pesticides under wet tropical conditions; and hence the integration of biological control in any management programme for this pest is desirable. The Commonwealth Institute of Biological Control (CIBC) with its network of stations, attempted to obtain parasites of *Spodoptera* spp. from various parts of the world and has provided stocks of parasites to several neotropical countries and has been actively engaged in a pest management programme for this pest in Trinidad since 1976. This paper summarizes parasite introductions undertaken by the Institute in the West Indies and Latin America and also the preliminary findings of the integrated programme mounted in Trinidad.

NATURAL ENEMIES OF *S. FRUGIPERDA* IN THE EASTERN CARIBBEAN

S. Frugiperda which occurs throughout the tropical and subtropical regions of America has a large complex of parasites. Ashley (1979) has listed over 70 species representing 43 genera and 10 families.

The published data on parasites reared from different stages of *S. frugiperda* field-collected in the Lesser Antilles (LA), Barbados and Trinidad are presented in Table 1.

During the present investigation, *Chelonus texanus* Cress. (Braconidae) and *Eiphosoma* sp. (Ichneumonidae) were reared from larvae in Trinidad. *Trichogramma* sp. (Trichogrammatidae) considered to be a new species by Dr. H. Nagaraja (CIBC, India) and a species of *Telenomus* (Scelionidae) were obtained from eggs of *S. frugiperda* in Guadeloupe. *Telenomus* sp. was also reared from eggs of *S. frugiperda* in the Dominican Republic.

INTRODUCED PARASITES

Investigations by the Indian and Pakistan stations of the CIBC have revealed a complex of parasites of *Spodoptera* spp. and related species in Southern Asia and the Pacific. Several of these have been tested against *S. frugiperda*. Also cultures of several South American parasites of *S. frugiperda* were also obtained for trials in the Caribbean (Table 2). In order to breed these parasites, cultures of *S. frugiperda* are maintained on a semisynthetic diet (Yaseen, 1978). With this diet, it has been possible to breed adequate numbers and to maintain cultures of up to 10 parasite species at the same time.

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TABLE 1. PARASITES OF *SPODOPTERA FRUGIPERDA* IN THE EASTERN CARIBBEAN

Family Parasite	Stage Attacked	Location	Reference
Braconidae			
Apanteles sp. (glomeratus group)	Larvae	Barbados, Trinidad	Alam, 1978 Yaseen, 1978
Apanteles marginiventris Cress	Larvae	LA	Fennah, 1947
Chelonus antillarum Marshall	Egg-Larval	Barbados	Alam, 1978
C. insularis Cress	Egg-Larval	LA	Fennah, 1947
Palinzele sp.	Larvae	Trinidad	Yaseen, 1978
Eulophidae			
Euplectrus plathypenae How.	Larvae	LA Barbados Trinidad	Fennah, 1947 Alam, 1978 Yaseen, 1978
Tachinidae			
Archytas analis Fab.	Larval-Pupal	Barbados	Alam, 1978
A. marmoratus (Townsend)	Larval-Pupal	Barbados Trinidad	Alam, 1978 Yaseen, 1978
A. piliventris Wulp	Larval-Pupal	LA Barbados	Fennah, 1947 Alam, 1978
Eucelatoria sp.	Larvae	Barbados	Alam, 1978
Gonia crassicornis F.		LA	Fennah, 1947
Frontina archippivora		LA	Fennah, 1947
Winthemia sp.	Larvae	LA Trinidad	Fennah, 1947 Yaseen, 1978
Sarcophagidae			
Sarcophaga lambens Wd.	Larvae	LA	Fennah, 1947
Trichogrammatidae			
Trichogramma fasciatum Perk (= *T. exiguum* Pinto & Platner)	Eggs	Barbados	Alam, 1978

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TABLE 2. INTRODUCED PARASITES TESTED FOR *SPODOPTERA* CONTROL IN THE CARIBBEAN

Family Parasite	Host	Stage Attacked	Origin
Braconidae			
Apanteles sp. (*Octonarius* group)	*Spodoptera litura* F.	Larvae	India
Apanteles ruficrus Haliday	*Agrotis* spp.	Larvae	Pakistan
Chelonus formosanus Scnan	*Spodoptera litura*	Egg-Larval	India
C. heliopae Gupta	*Spodoptera litura*	Egg-Larval	India
Macrocentrus collaris Spen.	*Agrotis* sp.	Larvae	Pakistan
Ichneumonidae			
Campoletis flavicincta (Ashm.)	*S. frugiperda*	Larvae	Uruguay
Eiphosoma vitticolle Cress	*S. frugiperda*	Larvae	Bolivia
Tachinidae			
Blepharekka lateralis Macq.	*Spodoptera litura*	Larval-pupal	India
Peribaea orbata Wied.	*Spodoptera litura*	Larval-Pupal	India
Scelionidae			
Telenomus nawai Ashm.	*S. mauritia* (Walk.)	Egg	Hawaii
T. remus Nixon	*S. mauritia* (Walk.)	Egg	Papua New Guinea Sarawak Malaysia

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INTEGRATED CONTROL PROGRAMME IN TRINIDAD

The incidence of most of the native parasites (see Table 1) and predators (e.g. *Polistes versicolor; Colemegilla* sp.) is low for much of the year and they do not provide effective control for *S. frugiperda* in Trinidad. Since 1976, CIBC has been involved with the Ministry of Agriculture in Trinidad in the establishment of an integrated programme for the control of pests of economic importance namely the armyworm and the earworm, *Heliothis zea* (Boddie) on corn, with CIBC providing the bio-control input.

Yaseen (op. cit.) reported on the extent of parasite releases during April 1976 to March 1978. These releases as well as those effected during April, 1978 to March 1981 are given in Table 3. Releases were made in farmers' holding at Macoya (in the county of East St. George) and in experimental plots at La Pastora, Valsayn (Texaco Food Crops Demonstration Farm), St. Augustine and Piarco.

In each trial, two (2) plots were established quite distant from each other e.g. one in La Pastora (Santa Cruz) and the other in St. Augustine. At one site only chemicals were applied, whereas at the other an integrated approach was adopted (the use of chemicals and parasites). The variety of corn used was Pioneer Hybrid selection, x304B. Approximately 1,080 plants were used at each site in a randomised block design with four (4) replicates per treatment. Chemicals used were Trichlorfon, Belmark (R), Acephate, Leptophos. In the chemical control trial pesticides were applied once when the plants were about 45cm high. In the integrated control experiment parasites were released at least ten (10) days prior to chemical application. To evaluate the effect of the control measures the innermost whorl of leaves of five (5) plants randomly selected in each replicate was removed and taken to the laboratory to determine the extent of damage.

Telenomus remus is considered by C.F.W. Muesebeck to be identical with or very close to *T. minutissimus* Ashm described from Trinidad and known to attack *Spodoptera* eggs in Puerto Rico. Specimens of *Telenomus* obtained from Guadeloupe and the Dominican Republic were determined as *T. remus* by Dr. Norman Johnson, Cornell University. In preliminary laboratory tests individuals from both the territories were separately cross bred with *T. remus* from our laboratory colony and two (2) generations were obtained indicating that they were the same or closely allied species. For this reason egg masses

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TABLE 3. RELEASES OF *SPODOPTERA* PARASITES IN TRINIDAD (April 1976 to March 1981)

Parasite	1976/78	1978/79	1979/80	1980/81	Total
Apanteles ruflicrus	5,000	–	–	–	5,000
Apanteles sp. (*Octinarious* group)	–	100	–	–	100
Campoletis flavicincta	–	–	65	553	618
Chelonus formasanus	1,105	2,358	2,850	990	7,303
Eiphosoma vittecole	–	–	–	100	100
Telenomus nawai	–	–	–	250	250
Telenomus remus	43,900	44,100	40,600	18,350	146,950

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of *Spodoptera* eggs were collected in Trinidad on a routine basis for more than two (2) years before making releases of *T. remus.* No parasite emerged from the several thousands of eggs collected prior to the release of *T. remus* whereas several post release recoveries have been recorded. This suggests that under Trinidad conditions *T. minutissimus* only occasionally attack eggs of *Spodoptera* or that it occurs only in certain types of habitats which were not sampled during our investigations, or that *T. remus* (origin pacific territories) is better adapted to the conditions in Trinidad and elsewhere in the Caribbean and Latin America e.g. Barbados and the Cauca Valley (Colombia). *T. remus* has also been recovered from experimental plots at Golden Grove Central Experiment Station/Field Station from eggs in 54 per cent of the egg masses collected in November, 1980. Only a few specimens of Eiphosoma and *Chelonus* were obtained from samples of larvae field-collected from the release sites and confirmation whether these are the released parasites from specialists is still awaited.

The results obtained in the integrated control experiments indicate so far that there is no significant difference between the methods of integrated control and chemical control. It was noted in 1977, 1979 and 1980 that the incidence of *S. frugiperda* in the test sites was low and the damage caused was less that five per cent. Of the chemicals investigated Trichlorphon and Belmark (R) gave the best results. Leptophos caused burning of the leaves.

BIOCONTROL IN THE LESSER ANTILLES

Commencing in 1971, thirteen (13) species of parasites obtained from CIBC stations were introduced in Barbados (Alam, 1974). Only *T.remus* and *Trichospilus pupivora* Ferriere, a Eulophid pupal parasite were established. The addition of *T. remus* into an area where there were no significant parasites is considered to have significantly increased mortality (Alam, 1978).

Biological control efforts in St. Kitts commenced in the last decade when approximately 6,000 eggs parasitised by *T. remus* were shipped from Trinidad and initial recoveries were made by one of us (FDB). Additional releases were made in 1975 but parasitism remained at a low level, 0.5 per cent in 1977 (Wilson, 1981). Further introductions made in 1980 included 745 *C. flavicincta,* 440 *Chelonus formosanus,* 5,500 *Telenomus nawai* and 7,500 *T. remus* obtained from CIBC, Trinidad and released in infested peanuts

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at three sites. *Telenomus* was recovered from the released sites as well as at other sites (Wilson op. cit.).

The CIBC has provided nucleus stocks or *T. remus* to several other territories in the region. The details are given in Table 4. Ing J. Gaviria (pers. comm.) reported establishment of the scelionid in the Cauca Valley, Colombia, with higher level of parasitism on *S. sunia* than on other species. Information as to releases and recovery surveys is not available. Detailed reports on releases or recoveries from other territories have not been made.

DISCUSSION AND CONCLUSION

In Trinidad, *Telenomus remus* has been released in fairly large numbers and while recoveries have been made there is no certainity that it has been extablished permanently. It has exerted adequate control in Barbados and with sustained efforts may provide an appreciable level of control in Trinidad expecially in areas where the incidence of the pest is high. Efforts are continuing to try and establish an integrated control programme in this country. Investigations at the CIBC stations in India, Pakistan and Europe have revealed several other parasites of *Spodoptera* spp. which may be given trials against *S. frugiperda*.

In St. Kitts, initial results of the releases made in 1980 are encouraging and provided the efforts are sustained satisfactory biological control might be obtained.

Several parasites occur over every point of the geographical range. Our present knowledge of the taxonomy of several parasite groups is incomplete and great care should be taken to ascertain the correct specific identity of a native parasite before introducing closely allied species of parasite.

In our experience, the egg parasite *Trichogramma* sp. is of little consequence as control agents for *S. frugiperda*. The coating of scales covering the egg-masses appear to deter *Trichogramma* spp. By contrast *Telenomus remus* appears to be attracted by them having possibly a karyomone effect.

The culture of *T. remus* used for most, if not all of the introduction into the Caribbean and Latin America originated from a relatively small initial

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TABLE 4. SHIPMENTS OF *TELENOMUS REMUS* TO VARIOUS TERRITORIES IN THE CARIBBEAN AND LATIN AMERICA

Country	No. shipped	Year
Antigua	700	1976
Bahamas	23,706	1976
Colombia	1,300	1976
El Salvador	2,000	1978
Guyana	6,200	1979, 1980
Mexico	6,300	1979, 1980
Nicaragua	500	1976
Suriname	3,000	1979
Venezuela	2,000	1979

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culture and hence contained very limited genetic variation. It would be worthwhile obtaining material from other areas to broaden the genetic base. Also surveys should be taken to seek out other species. *T.nawai* is known to attack eggs of *Spodoptera* spp. in Hawaii. Limited trials in Trinidad indicate that it will attack *S. frugiperda* in the laboratory and field trials are warranted. In contrast to *Trichogramma* spp. which can be readily cultured on eggs of several stored product pests neither *T. remus* nor *T. nawai* can be bred in the laboratory only of *Spodoptera* spp. and a few with closely allied *Lepidoptera.* This means that inundative releases can only be made if large-scale laboratory production of *Spodoptera* is undertaken. On the other hand *T. remus* is longer lived and particularly if karimones are involved in locating host eggs, it is probably a more efficient searcher than *Trichogramma* spp. and hence the numbers required for control are probably smaller. Certainly, there is plenty of scope for further introduction for biological control of *Spodoptera frugiperda* in the neotropics where it breeds continuously throughout the year.

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THE NEMATODES ASSOCIATED WITH PLANTAIN CROPS IN JAMAICA

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INTRODUCTION

Nematodes are limiting factors to the growth, vigour, stability, production and longevity of plantain crops (Hutton, Chung, 1973, Ogier, Merry, 1970, Roman, Rivas, Rodrigues, Oramas, 1976 and Wardlaw, 1972). In Jamaica, it is now recognised that if nematode control measures are not instituted from the outset, good plant crops are not produced and ratoon crops fail.

Several phyto-parasitic nematode genera have been found associated with and in some cases shown to cause light to severe damage to plantains in many countries (Gorenz, 1963, Hutton, Chung, 1973, Ogier, Merry, 1970, Roman, Rivas, Rodigues, Oramas, 1976, Stover, Fielding, 1952, Wardlaw, 1972 and Yepez, Julia, Meredith, Perez, 1972). In Jamaica, *Radopholus similis, Helicotylenchus* spp. and *Pratylenchus* spp. have been identified as the nematodes of greatest importance to plantain crops. Between 1970 and 1977, 21 plantain-growing holdings were visited in connection with surveys, research projects and advisory work. Opportunity was taken to identify the nematodes of potential importance associated with this crop throughout the country.

MATERIALS AND METHODS

Root and rhizosphere soil samples were taken from plantains at the holdings visited. Nematodes in soil samples were extracted on Whitehead's trays (Whitehead and Hemming, 1965) using 150 ml aliquots. A known weight of roots was comminuted in water in a blender for 40 seconds, the debris separated on one mm. over 0.25 mm sieves then the nematodes collected by passing the filtrate through a 0.044 mm sieve seven times. Nematodes from soil and root samples were identified and counted. Each genus was scored for its frequency of occurrence and highest density found in a particular location and for the percentage of locations in which it occured (Table 1).

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TABLE 1. FREQUENCY OF OCCURRENCE[a] (UPPER FIGURE) AND HIGHEST POPULATION DENSITY[b] (LOWER FIGURE) OF THE POTENTIALLY PARASITIC NEMATODES FOUND ASSOCIATED WITH PLANTAINS AT 21 LOCATIONS IN JAMAICA

LOCATIONS VISITED	GENERA OF NEMATODES FOUND[c]								
	RADOPHOLUS[r]	*HELICOTYLENCHUS*[h]	*ROTYLENCHULUS*[rr]	*MELOIDOGYNE*[m]	*PRATYLENCHUS*[p]	*PARATYLENCHUS*	*XIPHINEMA*[x]	*LONGIDORUS*	*TYLENCHORHYNCHUS*
Browns' Hall		100 (1)[b]	100 (2)		100 (1)				
Bushy Park	25 (1)	25 (2)		50 (2)	25 (1)				25 (2)
Cacoon Castle	83 (3)	100 (3)		67 (2)					
Caenwood	2 (3)	95 (4)	72 (5)	98 (4)	1 (1)	1 (2)			1 (2)
Dallas	100 (1)	100 (1)	100 (1)	100 (1)					
Halifax	100 (1)	100 (1)	100 (3)	100 (2)					
Highgate	100 (3)	100 (3)	100 (4)						

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TABLE 1 (Cont'd)

LOCATIONS VISITED	GENERA OF NEMATODES FOUND[c]								
	RADOPHOLUS[r]	*HELICOTYLENCHUS*[h]	*ROTYLENCHULUS*[rr]	*MELOIDOGYNE*[m]	*PRATYLENCHUS*[p]	*PARATYLENCHUS*	*XIPHINEMA*[x]	*LONGIDORUS*	*TYLENCHORHYNCHUS*
Linstead		100 (2)		100 (2)					
Kingston 3	50 (1)	25 (2)			75 (2)				
Kingston 6		100 (4)	100 (3)		100 (3)				
Mahogany Hall	67 (2)	33 (2)	100 (3)	33 (2)					
Orange River		85 (4)	98 (5)	32 (3)	22 (2)	2 (3)	3 (2)		2 (2)
Point Hill	91 (4)	74 (3)	74 (5)	37 (2)	20 (3)	3 (3)	23 (3)	3 (1)	
Smithfield	100 (3)	100 (3)		75 (2)	50 (2)				
Spanish Town	88 (2)		100 (3)	63 (3)	50 (3)				50 (2)
Spring	100 (2)	100 (3)	100 (3)	100 (2)	100 (2)				

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TABLE 1 (Cont'd)

LOCATIONS VISITED	GENERA OF NEMATODES FOUND[c]								
	RADOPHOLUS[r]	*HELICOTYLENCHUS*[h]	*ROTYLENCHULUS*[rr]	*MELOIDOGYNE*[m]	*PRATYLENCHUS*[p]	*PARATYLENCHUS*	*XIPHINEMA*[x]	*LONGIDORUS*	*TYLENCHORHYNCHUS*
Springvale	40 (1)	60 (2)			40 (2)	20 (2)			
Thompson Pen	100 (3)	100 (3)		100 (3)			67 (3)		
Tom's River		100 (3)	100 (3)	100 (3)	50 (2)				
Western Potosi	69 (4)	60 (4)	71 (5)	83 (5)	11 (3)			33 (4)	
Woodhall	96 (4)	58 (3)	64 (3)	2 (2)	26 (4)	36 (5)			
Locations where found (%)	76	95	67	76	67	24	14	10	19

[a]Percentage of samples in which nematode occurred

[b](1)–(5) indicating 1–10, 11–100, 101–500, 501–1, 500 and more than 1,500 nematodes per 100ml soil or per gm root respectively

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TABLE 1 (Cont'd)

[c] In addition, *Criconemoides* sp. was found at Caenwood and Western Potosi, *Cacopaurus* sp. at Point Hell and Woodhall, *Trichodorus* sp. at Caenwood, *Hoplolaimus* sp. at Point Hell, *Tylenchus* sp. at Caenwood and Western Potosi, *Ditylenchus* sp. at Tom's River and Western Potosi, *Aphelenchoides* sp. at Halifax and *Aphelenchus* sp. at Caenwood and Western Potosi.

[r] *Radopholus similis*

[h] Mainly *Helicotylenchus multicinctus* but *H. melancholichus*, *H. erythrinae* and *H. nannus* also identified

[rr] *Rotylenchulus reniformis*

[m] *Meloidogyne* spp. including *M. incognita*

[p] *Pratylenchus* spp. including *P. coffeae*

[x] *Xiphinema americanum*

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RESULTS AND DISCUSSION

Seventeen genera of nematodes of potential importance were found associated with plantains at 21 holdings in Jamaica (Table 1). *Radopholus similis* and *Helicotylenchus* spp. (mainly *H. multicinctus)* were most widely distributed, generally occurred in high populations in roots and soil respectively and were usually associated with uthriftiness of plants, poor production and high incidences of plants toppling when in waterlogged soils or under bunch weight of being blown over. These conditions were especially noticeable where nematode control was not practised. *Meloidogyne* spp. were found at 76 per cent of the holdings and in some instances population levels tended to be very high. However, even where the root-knot nematodes predominated in certain areas of some holdings, plants were usually vigorous and bore good-sized bunches and there were low incidences of plant loss. Yields of plantains and bananas do not appear to be seriously affected by the root-knot nematodes. In St. Lucia, Edmunds found *Rotylenchulus reniformis* to be of great importance in banana growing areas as under natural conditions the roots primarly responsible for nutrient and water uptake were affected (Edmunds, 1971). This nematode occurred at 67 per cent of Jamaican plantain holdings, very high populations being found in some instances, and appeared to be of limited importance especially when *Radopholus similis, Helicotylenchus* spp. and *Pratylenchus* spp. were absent or not yet dominant. *Pratylenchus* spp. were widely distributed but generally occurred in low numbers. However, in a field at Point Hill, *P. coffeae* was found exclusively and was associated with extremely unthrifty plants only a few of which bore bunches and these were under-sized. Many plants toppled or were blown over and in fact, the field was abandoned after 15 months. *Radopholus, Helicotylenchus, Meloidogyne, Rotylenchulus* and *Pratylenchus* were all found in soil and root samples.

The other nematodes were not widely distributed and were found only in soil samples. *Pratylenchus* sp., predominant at Woodhall, was associated with damage to fine roots and appeared to be somewhat responsible for unthrifty growth of plantain plants: *Longidorus* sp. was associated with root injury at Western Potosi. The genera *Criconemoides, Xiphinema, Cacopaurus, Tylenchorhynchus, Trichodorus, Hopolaimus, Tylenchus, Ditlenchus, Aphelenchoides* and *Aphelenchus* were, in general, not widely distributed and did not occur in high populations and seemed to be of little or no importance to plantain crops.

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Plantains have always been in demand for local consumption and for export but exports declined from 1,128 tons in 1970 to only 37 tons in 1976. Between 1970 and 1977, the area planted with "Horse" plantains rose from 836 to 2,185 then declined to 1,405 hectares. Yields declined from 9.0 to 5.8 tons/hectare and total production from 18,825 tons in 1974 to 8,119 tons in 1977 (figures supplied by the Agricultural Planning Unit, Ministry of Agriculture, Jamaica). When one sees so many nematode-infested plantain fields and little inclination towards nematode control, it seem safe to assume that nematodes must be somewhat responsible for the fluctuations observed in plantain production in Jamaica. Today, increased agricultural production is vital to Jamaica's economic development if there is to be increased production of plantains, special attention must be paid to nematode control.

SUMMARY

Seventeen phyto-parasitic nematode genera were associated with plantain crops at 21 locations. *Helicotylenchus* spp. (mainly *H. multicinctus), Radopholus similis, Meloidogyne* spp., *Pratylenchus* spp. and *Rotylenchulus reniformis* were found in soil and root samples from 95 per cent, 76 per cent, 76 per cent, 67 per cent and 67 per cent respectively of the locations. *Helicotylenchus* and *Radopholus* were generally associated with unthriftiness, poor production and high incidences of plant loss due to toppling or blow-down. *Pratylenchus* occurred mostly in low to moderate populations but at one holding, *P. coffeae* caused severe injury to and setback of plants resulting in early abondonment of the field. Nematodes of the genera *Radopholus, Helicotylenchus* and *Pratylenchus* have been shown to cause severe damage to plantain crops in Jamaica. High populations of *Rotylenchulus reniformis* were encountered in instances but this nematode appeared to be of limited importance and only when *Radopholus, Helicotylenchus* or *Pratylenchus* were absent or not yet dominant. *Meloidogyne* spp., although widespread, never appeared to cause significant damage to plantain crops.

The other nematodes *(Pratylenchus, Criconemoides, Xiphinema, Longidorus, Cacopaurus, Tylenchorhynchus, Trichodorus, Hoplolaimus, Tylenchus, Ditylenchus, Aphelenchoides* and *Aphelenchus)* were not widely distributed, were found only in soil and apart from *Paratylenchus* or *Longidorus* which seemed to be somewhat responsible for damage observed in two fields, appeared to be of little or no importance to this crop.

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SUSCEPTIBILITY OF SUGAR CANE VARIETIES IN BARBADOS TO *THRIPS* NR. SP. *FULMEKIOLA SERRATA* KOB. (THYSANOPTERA: TEREBRANTIA) AND THE EFFECT OF INSECTICIDES ON THE INSECT POPULATION: A PRELIMINARY STUDY

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INTRODUCTION

Sugarcane, the major export crop in Barbados, is attacked by many pests and disease organisms of varying economic importance. During the late 1920's, two insects, the sugarcane moth-borer, *Diatraea saccharalis* and the sugarcane root-borer, *Diaprepes abbreviatus,* achieved pest status, when they began to severely reduce sugarcane yields. An entomologist was immediately employed by the local Department of Agriculture, and he promptly embarked on a control programme aimed at reducing the population levels of these insects. Present indications are that *D. saccharalis* is controlled by predators and parasites (Cadogan, 1978; Alam, 1980; Jones, 1980), but an acceptable long-term measure is still to be achieved for *D. abbreviatus.* Some other insects and a few plant diseases have reached pest status occasionally. In late October 1980, the leaf tips of young plant-canes were observed to dry suddenly, and drying worsened despite frequent heavy rains.

Close examination indicated that most damaged plants contained large populations of thrips. These insects had not been reported previously on sugarcane in Barbados, although there have been many records of thrips severely damaging sugar cane in other sugarcane growing countries. It is beleived that this insect may have been introduced on winds during hurricane Allen.

Williams (1931) described the effect of a number of different thrips on sugarcanes in the Hawaiian Islands, and Box (1953) listed over 60 different species on sugarcane throughout the world, the vast majority being recorded from Asia. Puerto Rico, Trinidad and Tobago and Cuba were the West Indian islands included in this list. Williams (1956) described the varietal susceptibility of sugar canes to *Baliothrips (Fulmekiola serrata* Kob.) in Mauritius.

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Because of the interest created by the sudden appearance of this insect on sugarcane, a study was immediately started. The results of this preliminary study (covering the six-month period, November 1980 - April, 1981), are presented in this paper. The biology of the insect is outlined briefly, the effect of feeding on the most common sugarcane varieties is assessed, as well as the effectiveness of some selected insecticides on thrips population levels, both in the field and on artificially thrips-infested sugarcane plants in the greenhouse.

BIOLOGY

Eggs

Eggs of this thrips are elongated reinform in shape, measuring approximately 0.35mm long and 0.1mm wide (based on 25 measurements). They are smooth with no recognisable markings on the chorion. All eggs are laid singly within slits in the leaf blade. These slits are made by the ovipositor of the female during egg laying. All eggs were found within the leaf tissue (by using a binocular microscope) lying parallel to and between the vascular strands. The anterior portion of the eggs is the only part not embedded entirely within the leaf tissue. Freshly laid eggs are opaque, but as embryonic development occurs, they become shiny and transparent, with the red eyespots of the first nymph being quite distinct anteriorly. Eggs hatch in about 4-5 days at normal room temperature (23^{o}-$24^{o}C$) but hatching is undoubtedly quicker in the higher temperature conditions of the field.

Larvae

The larvae are pale-yellow in colour, with the first stage being barely visible to the naked eye. Development is quite rapid, and two distinct larval stages have been identified (based on head-capsule measurements). There is also a pre-pupa and pupa both of which are pale in colour. The pre-pupa is an inactive stage but the pupa, although normally inactive, becomes quite active when it is disturbed. The pupa can be further differentiated from the pre-pupa by its backwardly directed antennae.

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Adults

The adults of this insect are small and black. The dark pigmentation and the presence of fully developed wings readily distinguish them from the much paler immature stages. Adults are usually very active and will crawl or leap if disturbed. They produce a sharp sting when handled. Bailey (1936) reported a similar behaviour in onion thrips, *T. tabacci*, the larvae of which were more apt to bite; producing a prickling sensation which resulted in a slight itching but no swelling. These thrips seem to congregate within the younger rolled leaves of sugarcane plants (perhaps avoiding extremes of temperature and light), where eggs are laid and subsequent development occurs. There appears to be approximately twice as many adult females as males in populations, as a random sample of 518 adults contained 352 females and 166 males. Females are quite easily differentiated from males because of the presence of a well developed ovipositor and a more conical last abdonimal segment.

INJURY SYMPTOMS

Perhaps the most reliable indicator of the presence of thrips on sugarcanes is the type of the damage symptoms resulting from feeding. All stages of the life cycle of this insect occur on the leaves of the sugarcane. In this respect this thrip is unlike many others of economic importance where pupation occurs in the soil. As is typical of sucking insects, this insect shows a marked perference for young, soft, leaves and in the sugarcane these comprise the central spindle. The concentration of feeding activity in this area results in yellowing and finally drying of leaf tips. When this occurs the leaves are not able to unroll completely as in a healthy leaf, but they remain firmly joined at the tips unless separated by the wind. Other symptoms like discoloration of leaves, are usually typical of less severely affected plants. Field surveys indicated that most thrips are present in the tip region of the central leaf spindle, but in both greenhouse and laboratory studies conducted under cooler conditions, thrips left the security of the rolled leaves and crawled all over young unrolled ones. It is very likely that they behave similarly in the field.

Feeding on young leaves also produced distinct patches which ranged in colour from yellow through shades of red and brown. The older attacked leaves are usually silvery in colour. As would be expected, the damage symptoms are more pronounced under dry conditions and plants may be killed.

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VARIETAL SUSCEPTIBILITY

The sudden drying of leaves of sugarcanes in an experimental plot where one of the newer varieties was being tested, promoted a survey of the more commonly grown varieties, to determine whether the thrip exhibted any varietal preference, so that this factor could be utilised in a control strategy. Barbados is divided into three rainfall zones, – high, intermediate and low – and the survey was conducted on 52 plantations scattered throughout the island and covering all three zones. Ten sugarcane varieties were examined, a few of them being confined to a single rainfall zone. It will be noted that varieties B62163 and B63118 form the bulk of the sample (Table 1). These two varieties combined, presently account for about 74 per cent of the total sugarcane area under cultivation.

Relatively more varieties are grown in the high rainfall area because sugarcane is not irrigated in Barbados and few varieties yield well in low rainfall conditions.

Preliminary sample data showed that more than 95 per cent of the thrips on infested plants were found within the apical 25cm of the central leaf spindle. This 25cm portion was therefore selected as the sample unit for the survey programme. Twenty random samples per field were collected for popular varieties and 10 samples for all others. Samples were placed in plastic bags, labelled and brought back to the laboratory where thrips were transferred to alcohol in petri dishes using camel hair brushes. It was eventually decided not to include first instar larvae in counts because extremely small size and large numbers made accurate counting almost impossible. All other stages were counted.

The mean number of thrips found on varieties B73385 and B71235 in the high rainfall zone was appreciably higher than for any of the other varieties (Table 1). However, because only a few samples of these varieties were collected, more extensive sampling over a longer period is required to fully determine the accuracy of this statement. The same is true for variety B72177 in the low rainfall zone. Its mean of only 4.8 is appreciably smaller than all other varieties from any zone, but as only 30 samples were examined further data are required.

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TABLE 1. INFESTATION LEVELS OF THRIPS SP. ON DIFFERENT SUGAR CANE VARIETIES IN HIGH, INTERMEDIATE AND LOW RAINFALL AREAS OF BARBADOS BETWEEN NOVEMBER, 1980–APRIL, 1981

Variety	No of plants examined	Mean no. of thrips/plant	Range of thrips/plant	S.E.
		Low Rainfall Zone		
B62163	170	15.9	3–51	4.8
B63118	140	14.2	3–29	3.2
B73385	25	19.9	2–25	–
B72177	30	4.8	4– 5	–
		Intermediate Rainfall Zone		
B62163	260	17.5	2–44	3.4
B63118	130	16.1	3–31	4.3
B73385	40	18.9	15–22	1.9
B59136	40	15.5	9–23	–
B7316	50	11.6	2–22	4.3
		High Rainfall Zone		
B62163	420	22.6	7–53	2.5
B63118	170	23.1	15–34	2.3
B73382	20	12.6	4–17	–
B73385	20	52.1	12–91	–
B74541	25	10.3	8–12	–
B71235	40	32.3	25–35	–
B7316	80	24.8	9–46	–
B7274	20	13.9	12–15	–

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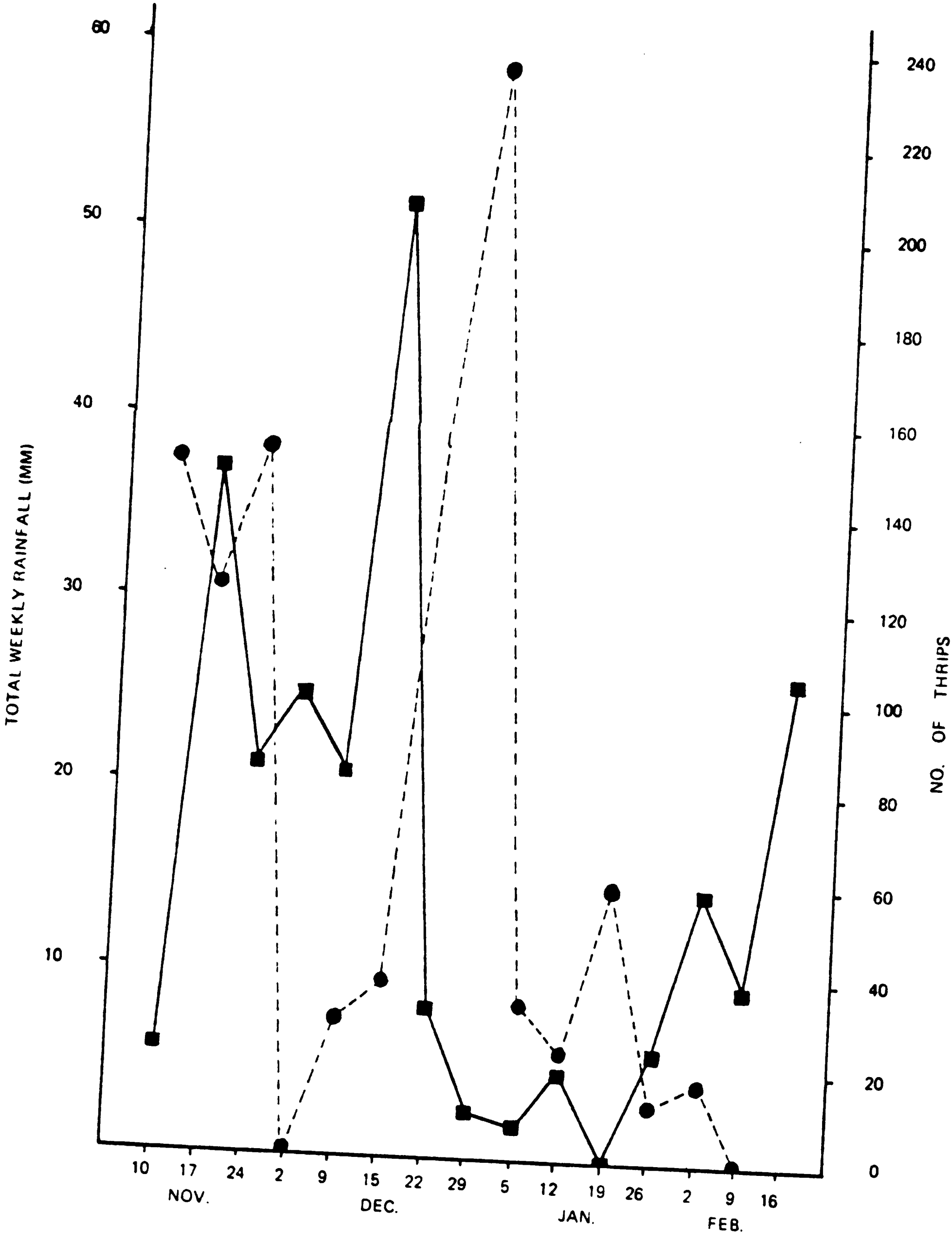

FIG. 1. TOTAL WEEKLY RAINFALL (■) AND NUMBER OF THRIPS PER 10 PLANTS (•) DURING NOVEMBER 1980 – FEBRUARY 1981, AT CENTRAL AGRONOMIC RESEARCH STATION, GRAEME HALL, CHRIST CHURCH, BARBADOS

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Observations made both in the field and in the greenhouse indicate that young cane plants are far more susceptible to attack than mature ones. Sixty samples collected from mature B62163 plants contained only 13 thrips while 20 thrips were found on 40 samples of mature B63118 plants. All thrips were found in the central rolled leaves of the spindle. Thrips seem to prefer the younger plants and as a result all samples collected during the varietal survey were taken from young plants which were less than 1m tall.

INFESTATION LEVEL

The infestation level of thrips on sugarcane fluctuated considerably throughout the duration of this study. This was very noticeable in weekly samples collected from the controlled untreated insecticidal trial areas. Predators and parasites were conspiciously absent when colonies of thrips were examined, and population fluctuations could not therefore, be attributed to these natural controlling factors. Abiotic factors were therefore considered. Close examination of sampling data indicated that the most dramatic decline in population levels occurred almost immediately following heavy rains, and when the total weekly rainfall was plotted against the number of thrips obtained from weekly samples, a close relationship was obtained (Fig. 1). Apparently populations build up relatively unchecked in dry conditions and light showers have minimal effect in reducing this build-up. As most thrips are found within the rolled central leaf spindle, it appears very likely that they could be seriously affected by rain unless they leave this shelter and roam over the leaf surface. Small droplets of water remain on the leaves after heavy rains and under such cool conditions thrips leaving the spindle to roam on the open leaves, could be entrapped in the water droplets or fall prey to any predators that may be present. This seems to be the most plausible explanation since no water collects in the central spindle where thrips colonies are found.

INSECTICIDAL CONTROL

The control of any new insect pest on sugarcane in Barbados is influenced considerably by programmes already in progress. One such programme has been going on for close to 50 years, and involves the biological control of the sugarcane moth bearer, *D. saccharalis*, by a number of parasites and predators, the most important ones being *Apanteles flavipes* and *Lixophaga diatraeae*.

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Because of this programme pesticides are seldom sprayed onto sugarcane foilage in Barbados and any new control strategy must therefore recognise this limiting factor. There are few records of predators of predators of parasites associated with thrips of sugarcane. Williams (1931) found little wasps, *Thripoctenus* sp., which parasitize them. This is not surprising, as the location of these insects within the sugarcane leaf spindle makes them inaccessible to most organisms, particularly the much bigger predators. An insecticidal control programme against thrips on sugarcane was therefore initiated, using systemic soil insecticides in an attempt to reduce population levels and, consequently, the associated damage to canes.

Two field and one greenhouse trials were set up to test the effect of insecticides on *Thrips* sp. nr. *sylvanus.* A field trial was set up in the high rainfall area and the other in the low one. These experiments were arranged in completely randomised block design. Each plot measured 10m long and consisted of a single row of plants spaced approximately 0.5m apart. Each row was separated by furrows on either side. Treatments were replicated three times. The experiments were set up in plant canes (variety B62163) which measured between 0.5 and 1.0 m in height at the time of application of the insecticides. Insecticided were broadcast around the base of the plants and 10 samples per treatment were collected every week for a period of 10 weeks, with the first samples being collected a week after the first heavy rainfall. Rain is required to dissolve the pesticide in the absence of irrigation. Sample units were similar to those in the varietal experiments outlined above. The percentage control achieved was estimated at the 4th and 10th weeks sampling stages. As was the case with the varietal samples, only the larger instars and adult thrips were counted.

In the greenhouse experiment, eight insecticides were tested on young thrips-infested sugarcane plants of variety B62163 (Table 2). These plants were grown from cuttings in 15cm plastic pots which contained soil. When the plants reached approximately 0.5cm high, 50 adult thrips were transferred to each plant. These thrips were collected from heavily infested sugarcane plants in the field and were transferred onto greenhouse plants with a soft comel's hair brush. Insecticides were applied to the soil around the base of the plant two days later. Each insecticide treatment was replicated 20 times and plants were watered twice weekly. Counts were made of adult thrips on four plants per treatment at intervals of 0.5, 1.0, 1.5 and 2.0 weeks after ex-

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TABLE 2. EFFECT OF SELECTED SOIL INSECTICIDES ON THRIPS ON SUGAR CANE PLANTS IN THE GREENHOUSE

Insecticide	Common name	Concentration kg/ha	% mortality after exposure at different time intervals (weeks)			
			0.5	1	1.5	2
Anthio 33	formothion	1.12	50	100	100	100
		2.24	80	100	100	100
Basudin 60 WP	diazinon	1.12	28	50	60	50
		2.24	20	55	100	100
Di-Syston LOG	disulfoton	1.12	100	100	100	100
		2.24	100	100	100	100
Furadan LOG	carbofuran	1.12	80	94	100	100
		2.24	85	86	100	100
Kilval 40 EC	vamidothion	1.12	78	100	100	100
		2.24	87	100	100	100
Metasystox-R 25 EC	pxydemeton-methyl	1.12	85	100	100	100
		2.24	70	100	100	100
Miral LOG	isophos	1.12	40	100	100	100
		2.24	70	100	100	100
Orthene 75 S	acephate	1.12	60	100	100	100
		2.24	85	100	100	100
Control (untreated)			10	15	15	15

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posure to the insecticides. The thrips were transferred to alcohol as outlined above, and counted under a binocular microscope.

The results of the field trials are given in Table 3. In the high rainfall trial Miral LOG, Furadan LOG, Basudin 60 WP and Di-syston LOG reduced thrips numbers significantly at the four week stage, and this was also achieved at the 10 week stage, for all except Basudin.

In the low rainfall trial, the same four insecticides gave significant kill at both intervals while primicid reduced thrips numbers significantly at the 10 week stage. The reason for Primicid's performance is uncertain, but the generally superior performance of most of the chemicals at the 10 week stage in the low rainfall area, as compared with the high rainfall may be attributed to the faster rate of removal of the chemicals by rain water. This performance of the granular formulations may also be due to the inherently more toxic nature of these chemicals, as well as the more controlled and much slower release of poison from this formulation when compared with emulsifiable concentrates and powders (Nation, 1972).

Under more controlled conditions in the greenhouse experiment, closer scrunity of the insecticides could be made. The first indicator of insecticide activity on the thrips was the change in behavious, many of them becoming hyperactive and crawling very disorientatedly over the leaves. Such behaviour was never observed in normal thrips populations in the field.

Many of the insecticides killed all thrips a week after treatment (Table 3). Again the granular insecticides were most effective although Anthio 33, Metasystox-R (E.C's) and Orthene (WP) gave satisfactory results as well.

DISCUSSION

The sudden appearance of thrips on sugarcane in Barbados in the wake of hurricane Allen has caused much concern among sugarcane farmers. This new attack comes less than a year after rust and smut have been recorded on sugarcane here for the first time. It will be sometime yet before the effect of the present attack can be fully assessed, but if the appearance of affected fields is any indication then the effect is likely to be quiet considerable.

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TABLE 3. EFFECT OF INSECTICIDES ON THRIPS ON SUGAR CANES IN HIGH (A) AND LOW (B) RAINFALL AREAS IN BARBADOS

Insecticide	Common name	A.I./ ha kg	Mean no. of thrips/ 10 plants	% control (after 4 wks)	Mean no. of thrips/ 10 plants	% control (after 10 wks)
			"A"			
Miral LOG	isophos	1.68	4	97 b	23	89 b
Primicid LOG	pirimiphos-ethyl	2.24	120	2 a	347	a
Furadan LOG	carbofuran	1.68	3	98 b	30	85 b
Basudin 60 WP	diazinon	2.24	20	79 b	125	39 a
Di-Syston LOG	disulfoton	1.68	5	97 b	15	93 b
Control (untreated)			123	-- a	206	a
			"B"			
Miral LOG	isophos	1.68	18	92 b	44	23 a
Primicid LOG	pirimiphos-ethyl	2.24	173	26 a	19	67 ab
Furadan LOG	carbofuran	1.68	20	91 b	1	98 b
Basudin 60 WP	basudin	2.24	6	97 b	9	84 b
Di-Syston LOG	disulfoton	1.68	4	98 b	1	98 b
Control (untreated)			223	-- a	57	a

Means followed by the same letter are not significantly different at 5% level of probability.

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The damage symptoms of thrips are quite different in appearance from any of those associated without local disease and pest problems of sugarcanes, and easy recognition and consequently prompt action is afforded. Many varieties are presently grown and new ones are continually being tested and released to farmers. All varieties surveyed so far showed signs of attack although the differing susceptibilities are yet to be fully examined. At present local breeding and selection programmes of sugarcane concentrate mainly on agronomic characteristics, but it is advisable that very serious consideration be given to thrips and other major pests and diseases, as there is little doubt that they cause significant reductions in yeilds, particularly in the low rainfall areas.

Varietal selection gains greater importance since no predators or parasites have been found in any of the thrips populations examined, and control, at least in the initial stages, will be heavily biased towards insecticides. The application of these chemicals to the root system of sugarcane is difficult and satisfactory control of the soil insects *D. abbreviatus* and *Clemora smithi* has never been achieved. In ratoons when trash cover is present the difficulty is magnified. However, thrips, because of their mode of feeding, are more amenable to such measures and much better results are anticipated.

One very important aspect of the behaviour of the sugarcane thrips which tends to increase the problems of young plants, is that there is an almost total avoidance of mature plants. This preference for young plants is perhaps due to the ease with which the mouth parts of the thrips can penetrate the young leaves, and the chemical nature of the food. Colour may also influence this preference. Because of the large acreage of canes planted in Barbados, there is always an abundance of young canes available. It is therefore very likely that this insect will continue to be a problem for a long time, and although its effect on sugarcane yields is not presently known, preliminary studies suggest that conditions are quite favourable for population build-up, and the insect possesses the potential to become a major sugarcane pest.

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The thrips was identified by Dr. W.R. Richard of the Biosystematics Section, Canadian Department of Agriculture, Ottawa. His assistance is greately appreciated.

SUMMARY

In 1980, sugarcane in Barbados and some of the other Caribbean islands was attacked by thrips for the first time. Indications are that the insects were introduced by the winds of hurricane Allen in August, 1980 and most of the damage so far has been confined to plant canes.

An island-wide survey conducted on ten popular varieties of canes indicated that B62163 and B63118 suffered substantial damage. These two varieties together comprise over 70 per cent of all sugarcane grown locally. Young plants are preferred to mature ones.

All stages of the life cycle of the thrips occurred on the leaves of sugarcanes, with the vast majority of the insect population being found between the rolled central spindle of young leaves.

Population levels are reduced considerably by heavy rains and Carbofuran, Disulfoton and Isophos at concentrations of 1.12 and 2.24 kg/ha gave satisfactory control of thrips in the field. No predators or parasites have been observed.

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URGENT PLANT PEST AND DISEASE PROBLEMS IN THE CARIBBEAN

Título

Fecha Devolución	Nombre del solicitante
31 MAR 1992	Enrique Alarcón
31 MAY 1994	A. Arias

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