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PROCEEDINGS OF THE INTERNATIONAL WORKSHOP ON THE CASSAVA MEALYBUG *PHENACOCCUS MANIHOTI* MAT-FERR. *(PSEUDOCOCCIDAE)*

Edited by
Kanayo F. Nwanze and Klaus Leuschner

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PROCEEDINGS OF THE INTERNATIONAL WORKSHOP ON THE CASSAVA MEALYBUG, PHENACOCCUS MANIHOTI MAT-FERR. (PSEUDOCOCCIDAE).

Held at INERA-M'vuazi, Bas-Zaire, Zaire

June 26 - 29, 1977

Edited by Kanayo F. NWANZE and Klaus LEUSCHNER

Co-sponsored by :

The International Institute of Tropical Agriculture, Ibadan, Nigeria

and

The Department of Agriculture, Kinshasa, Republic of Zaire.

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IITA's ROLE IN TROPICAL AGRICULTURE WITH SPECIAL REFERENCE TO PROGRAM NATIONAL MANIOC, ZAIRE.

S.K. Hahn
International Institute of Tropical Agriculture, Ibadan.

Honorable Minister and Director General
of Ministry of Agriculture

Ladies and Gentlemen:

It is a honor for me to welcome you to this Mealybug Workshop on behalf of Dr. William Gamble, Director General of the International Institute of Tropical Agriculture and on behalf of its Root and Tuber Improvement Program.

Let me first introduce briefly our Institute and its Root and Tuber Program. The International Institute of Tropical Agriculture was established in 1967, 10 years ago, to improve the quantity and quality of food production in the humid and sub-humid tropics. The Institute's prime responsibilities are: to improve selected, important food crops, to find practical alternatives to shifting cultivation and bush fallow systems, to increase land use and maintain soil productivity in these zones. Its responsibilities logically extend to disseminating information on these alternatives to interested international, governmental and professional groups and to individual scientists around the world. The Institute has three major activities which are research, training and outreach. In research, there are four programs namely: Farming Systems, Cereal Improvement, Grain Legume Improvement and Root and Tuber Improvement. For outreach, there are currently six programs in Nigeria, Liberia, Sierra Leone, Cameroon, Tanzania and Zaire where we have the Program National Manioc at this Station.

The Root and Tuber Improvement Program of IITA covers cassava, yams, sweet potato, and cocoyams in that order of priority. The broad objectives of the program are to develop improved cultural practices and to produce varieties with high stable yield, high quality, and improved plant characteristics suitable for efficient cropping systems. To achieve these objectives effectively and efficiently, the program has an interdisciplinary team approach involving agronomy, breeding, entomology, pathology, physiology and biochemistry all working towards a common goal. The program consists of the core program and three outreach programs: Program National Manioc in Zaire, National Cassava Program in Nigeria and the National Root and Tuber Improvement Program in Cameroon. In 1978, we expect to establish the National Root and Tuber Program in Tanzania.

Cassava was probably first introduced by the Portuguese at the mouth of River Zaire in the latter part of the sixteenth century, but its spread in the interior of Zaire and further into Burundi, Rwanda, Uganda and North-western Tanzania was probably done by Zairois and Congolese traveling up the River Zaire through the grasslands and lakes after 1900. Cassava was freely adopted by Zairean farmers who found in it a welcome addition to their traditional agriculture complex. It has since become most important both in total area devoted to its production and as a major component of the diet. Zaire is the largest cassava producing country in Africa. About 9 million tons of cassava are annually produced from 1 million hectares of land. In Zaire, both tuberous root and leaves of cassava are widely used and more than 58% of caloric intake comes from this plant.

Cassava is potentially able to produce more calories per unit area than any other food crop, owing to its high yielding ability, adaptation to diverse climate and cultural conditions, and ability to survive long (4-6 months) dry seasons. It generally requires less labor, costs less to produce, and needs less care in management than cereal crops. Both root and leaf are valuable as human food and livestock feed and the root is widely used for industrial production of starch and alcohol.

In March of 1972, at the request of the Government of Zaire, a team from IITA was sent to Zaire to investigate the disease problem in Zaire. Dr. Williams who is a pathologist and I visited Zaire and made a survey. It was reported to Citoyen Mukendi, Director General, Department of Agriculture that the so called candle disease in manioc was due to bacteria, Pseudomonas manihotis. In the report it was also pointed out that the high incidence, over 90% in some fields, of bunchy-top symptom was associated with large colonies of mealy-bugs in the environs of Kinshasa. Infested plants were stunted and considerable yield reduction both of tops and roots was likely to be caused by this insect. The symptoms were not observed in M'vuazi and Kikwit.

Subsequent to out visit, Citoyen Mukendi requested IITA to establish a Program National Manioc in Zaire. A Memorandum of Understanding between the Government of Zaire and IITA to establish the program was executed in May 1974 with the following main research objectives:

1. to identify and develop manioc varieties with superior yield.

2. to identify source of resistance to the major diseases and pests of manioc and to incorporate the resistance into high yielding potential varieties.

3. to develop a package of cultural practices which will allow yield to reach the economic optimum.

4. to develop high quality manioc varieties in terms of consumer acceptance and high protein in leaves.

The training objective will be to develop a cadre of Zairean personnel sufficiently trained and motivated to play a major role in the program and to lead and operate the entire program at an early date.

IITA participation in the Program National Manioc began in November 1974 with the arrival in Zaire of Dr. Ezumah, a plant breeder. In July 1976, Mr. Haynes joined the program as the project leader and agronomist. In September 1976, Dr. Pacumbaba, a plant pathologist, also joined the team. In January 1977, Dr. Nwanze joined the program as an entomologist. The program is now fully staffed.

Dr. Ezumah has introduced from IITA the improved seeds of cassava which contain source of resistance to cassava mosaic disease (CMD), cassava bacterial blight disease (CBB) and other desirable agronomic traits and he has since raised several hundred thousand seedlings and screened them for resistance to the diseases. As a result, he has been very successful in producing cassava clones which are highly resistant to these two diseases.

While Dr. Ezumah was evaluating cassava breeding materials, particularly for resistance to CMD and CBB, he made a survey in 1975 and reported that mealybug was a very serious pest of cassava in Bas Zaire. Dr. Schaefers, a visiting entomologist, visited Zaire in May 1975 and brought back the specimens of the mealybug which Dr. Leuschner subsequently sent to the Commonwealth Institute of Entomology for identification. It proved to be an unknown species in the genus Phenacoccus (Pseudococcidae) which is also found in Brazil.

The executive members of Board of Trustees of IITA with the Director General of Department of Agriculture and Delequé General INERA, Zaire visited the Program National Manioc at M'vuazi, Zaire in November 1976. When the members saw the serious mealybug problem, they instructed us to take urgent action in connection with the pest. At a meeting with the Board Members at the presence of Director General, Department of Agriculture and Deleque General INERA, at the Ministry of Agriculture, Zaire, it was mentioned by the speaker that it was very likely that the grenn mite, Mononychellus tanajoa, which had been accidentally introduced into Uganda from Latin America in 1972 is already established in Zaire, in view of the fact that the insect has been observed in Burundi near the border of Zaire. The presence of the insect in Kivu area has recently been confirmed by Dr. Leuschner, Dr. Nwanze, and Dr. Ezumah.

In Zaire there are presently three major economic diseases: cassava mosaic disease (CMD), cassava bacterial blight disease (CBB) and anthracnose disease. There are two major pests namely mealybug and green mite. As I mentioned earlier, we have have been very successful in breeding cassava for multiple resistance to these diseases. However, the insect problems, especially mealybug problem, need to be tackled as a matter of urgency. Your contribution at this workshop and your continuous support afterward in solving of the mealybug problem will be very much appreciated. Your efforts will contribute tremendously to the economy of Zaire and to the quality of life of Zairois and Africans who depend on cassava as their major food.

The objectives of this mealybug workshop are:

1. to exchange relevant information on the mealybug problem
2. to identify the most efficient methods of its control
3. to draw up a recommendation for a working program for the control of the pest.

Please be aware that you are holding a meeting at an historical area, an area where cassava was first introduced into Africa.

Thank you for your participation at this workshop.

SOME NOTES ON THE MEALYBUG (PHENACOCCUS MANIHOTI, MAT.-FERR.) INCIDENCE ON MANIOC (MANIHOT ESCULENTA) IN BAS-ZAIRE.

H.C. Ezumah and A. Knight.[1]

Introduction :

Although the mealybug of manioc may have existed for sometime in Zaire, it was first reported during a trip to the Republic of Zaire in 1972 (Hahn & Williams, 1972) when some samples of the mealybug were collected from a manioc field near the National University of Zaire. In 1975 after the specimens from Zaire and Brazil were sent to the Commonwealth Institute of Entomology, the pest was declared a new species on manioc in Africa. Some preliminary information was obtained on the relationship between the pest and the environment, the severity of damage on manioc caused by the pest and its effect on yield distribution of breeding clones at the preliminary yield trial (PYT) phase (IITA,1976). A method of uniform artificial infestation to enable the screening of clones and seedlings was also developed. Field evaluation method was developed using a 1 to 5 score to record damage severity. Drawing from a knowledge on pre-plant treatment of pineapple slips, an insecticide mixture was used for the treatment of manioc cuttings and a field experiment was conducted at M'vuazi using this formulation.

1. Observations on environmental conditions and Mealybug incidence:

Some environmental conditions which have been observed to enhance mealybug incidence and severity include dry weather conditions, soil moisture stress and soil erosion and subsequent loss of nutrients and organic matter.

Changes in mealybug severity rating with time

With decline in rainfall, the severity of mealybug incidence increases (Fig.1). Proportion of heavily infested clones (about 1000) in a preliminary yield trial (PYT) plot at Kimpese (a highly eroded field) was 100% in October compared with 52% in June. With high rainfall in March the following year about 90% of the clones were symptomless. Corresponding proportions of symptomless clones in June, October and November were 30, 0 and 0% respectively

Soil nutrient status

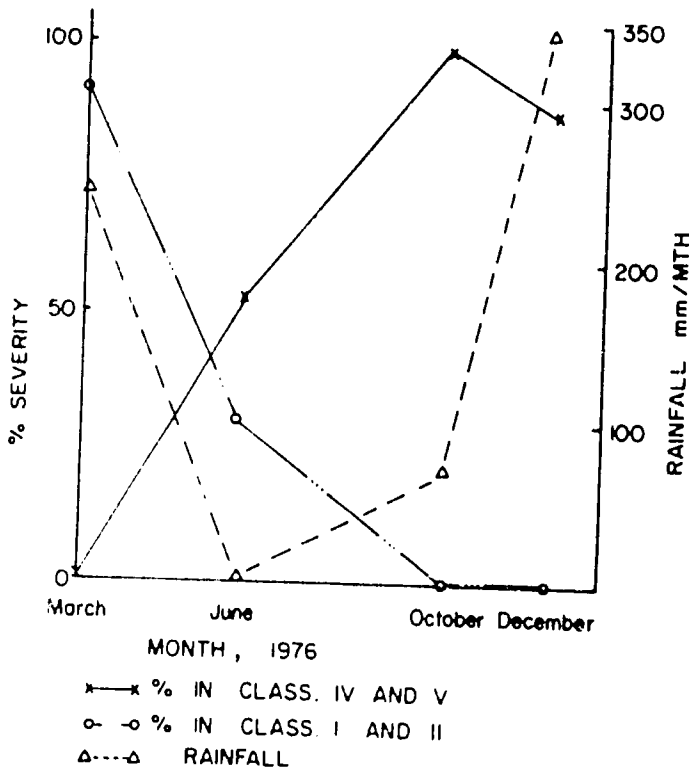
Differences have been observed between the severity of mealybug infestation in highly eroded soil compared with soils in which pockets of organic matter were intact. The pest is more severe in eroded soils and on slopes. Such differences in severity due to loss of soil nutrient and organic matter have been observed with the same field planted with the same manioc cultivar in CEDECO, Kimpese.

---

1. Breeder, IITA/PRONAM, INERA-M'Vuazi and Conseiller, Centre de Developpement Rural (CEDECO), Kimpese.

Figure 1

MEALYBUG SEVERITY RATING IN RELATION TO RAINFALL AT KIMPESE, BAS-ZAIRE 1976



Soil moisture stress

Mealybug incidence and severity is less serious in the M'vuazi river valley with rich alluvial soil deposit and high water table in contrast to sandy areas which lack soil moisture. Thus the pest severity is confounded by soil moisture stress.

2. Effect of malathion treatment of manioc cuttings on Mealybug incidence :

Cuttings of manioc, var. "Mpelolongi" were treated with an insecticide formulation at time of planting (25 ml malathion 50, 300 ml diesel oil, 10 litres water and 50 g soap powder). The cuttings were allowed to soak in the solution for two minutes and spread in the sun to drain for 5 hours. In January 1976 two sets, each of fourteen treated and untreated plots of 35 per plot (effective area), were established in a completely randomized block design. Mealybug severity scores were taken at two months intervals starting from two months after plot establishment. No further malathion treatment was introduced. Root yield was recorded at 14 months.

Results and discussion :

Figure 2a shows the percentage of manioc plants with mealybug infestation at different ages: Damage severity scores are illustrated in figure 2b. Pre-treatment of cuttings at rates used does not reduce mealybug incidence and damage. Incidence (Fig.2a) and damage severity (Fig. 2b) increase during the dry season and decline rapidly during rainy season. No difference in root yield resulted from pre-treatment of cuttings (Table 1).

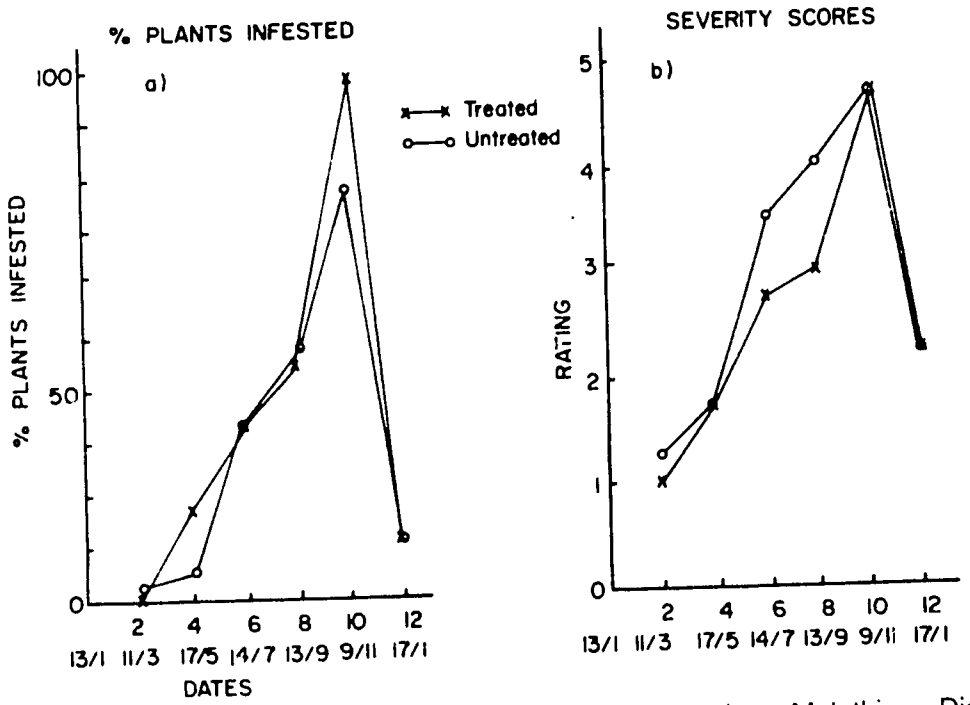


Fig 2. Effect of pre-plant treatment of manioc cuttings Malathion - Diesel oil mixture on (a) percent mealybug incidence at different ages and (b) Symptom severity scores

(1 = Symptom free; 5 = Death).

Reports of non-uniformity in setting of roots from heavily infested fields have been received suggesting an adverse effect on root quality. Plans for a more detailed quality observations (vascularity, vasculature and pith - area ratio) were dropped when a few samples from treated and untreated plots showed no differences. However, the study on quality should be intensified when techniques for maintaining symptom free fields are developed.

Table 1

Effect of pre-plant treatment of manioc cuttings on root yield of the Mpelolongi cultivar.

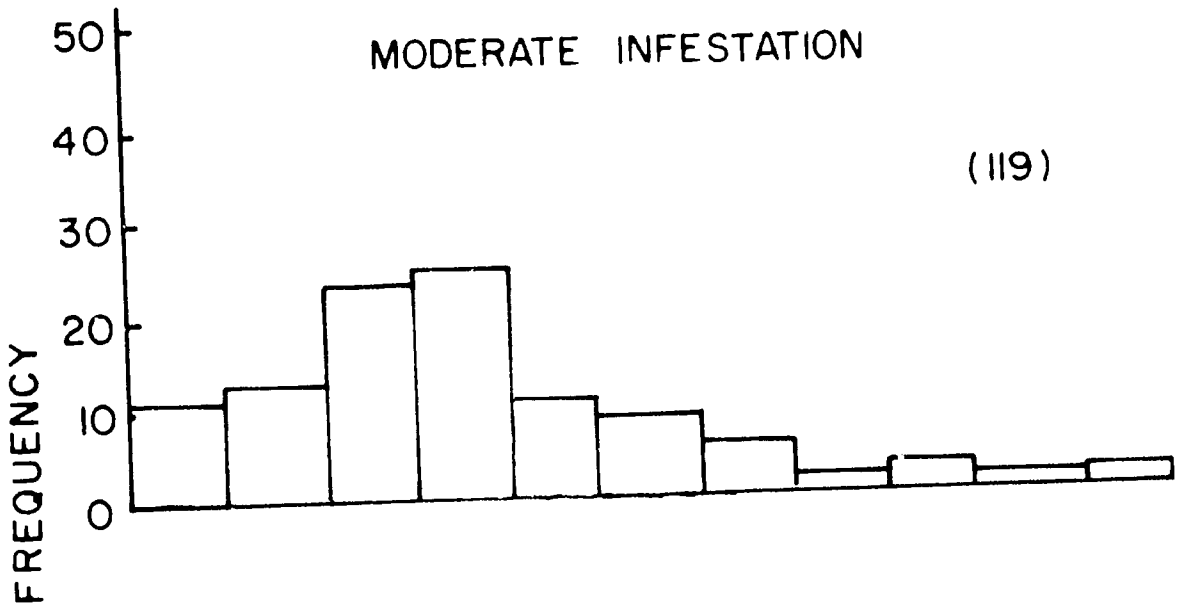
	Treated		Untreated
No. of plots	12		14
Effective plot area (m^2)	35		35
Average Yield (T/Ha)	27.4		26.6
't' value calculated		0.212	
t 0.05, df 24		2.064	
CV (%)		14	

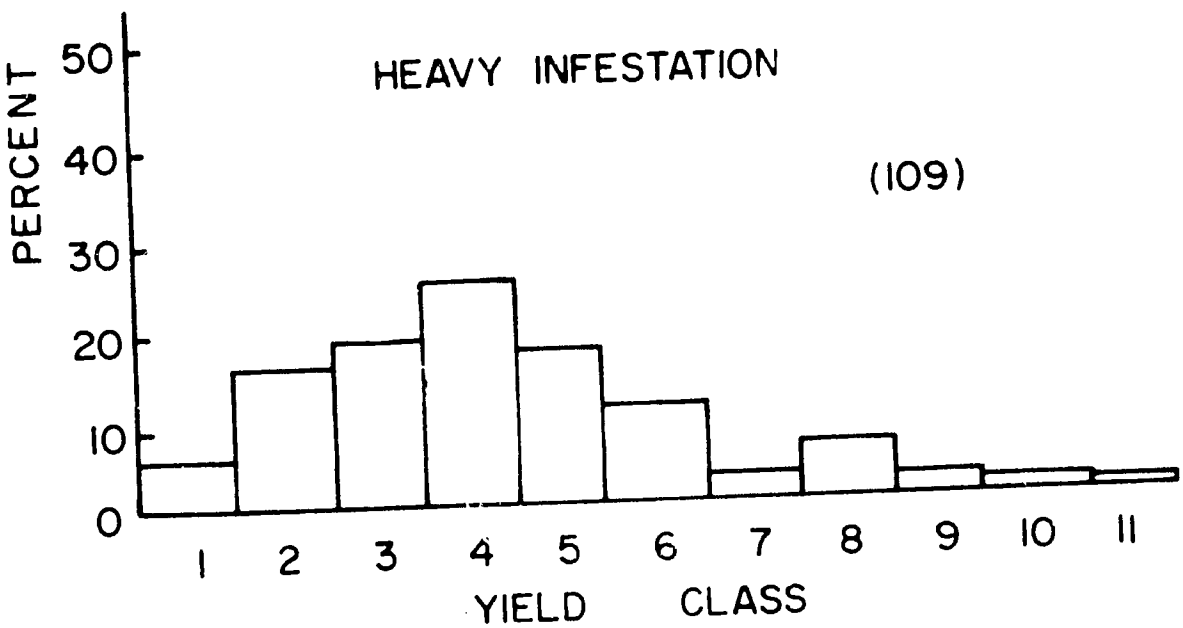
Relationship of Mealybug infestation with Yield Distribution of manioc clones in PYT breeding plots at two sites.

Two locations were chosen for detailed study of yield distribution of manioc clones as affected by the severity of mealybug infestation. These were:

a) M'vuazi river valley with a high water table and rich alluvial soil deposit and

b) Kimpese site, a highly eroded poor soil which often lacks soil moisture. Under M'vuazi conditions, clones with heavy mealybug infestation yielded as high as those with moderate infestation (Figure 3). Distribution at M'Vuazi was normal and yields greater than 5.0 kg per plant at 1 x 1 m^2 spacing were obtained in spite of mealybug attacks. In contrast with yield distribution at M'vuazi, heavy infestation by the rest resulted in a skewed curve favouring clones with low yields (Figure 4). Selections yielding greater than 2.4 kg per plant were available among those rated in classes I, II and III. Highest yielding clones in classes IV and V were in ranges of 1.6 - 2.0 and 1.2 - 1.6, kg per plant respectively. Mean relative difference in yield between clones in classes I, II, III and those in IV and V at Kimpese was estimated as 33% reduction.





Class : Kg / Plant : 1 = 0.1 - 0.5
at increments of 0.5
to class 11 > = 5.0

Fig 3. RELATIONSHIP OF MEALY BUG INFESTATION WITH YIELD DISTRIBUTION FROM PYT PLOT, M'VUAZI.

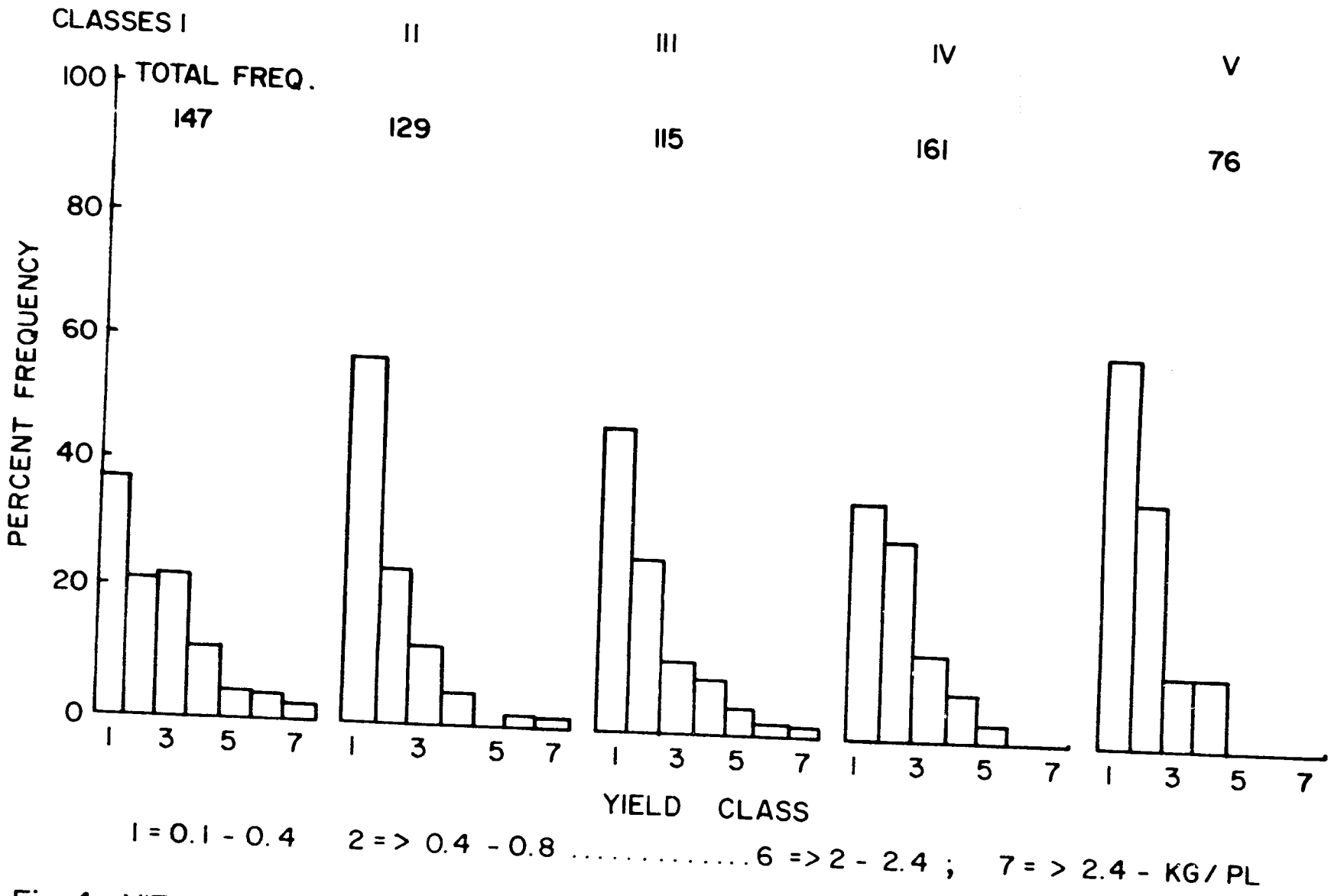


Fig 4. YIELD DISTRIBUTION OF MANIOC CLONES AS AFFECTED BY MEALYBUG INFESTATION AT KIMPESE, ZAIRE.

Breeding for resistance :

In order to screen for mealybug resistance, a method of uniform artificial infestation was achieved by attaching infested manioc twigs near the apex of a manioc branch with the aid of a twine or by using office pins. The insect readily moved from the twig to the growing point of its host and symptoms were observed within a week. Using this approach, about 400 and 1000 clones were artificially infested at M'vuazi and Kimpese, respectively. Variations in severity of infestation was observed suggesting a possibility for isolating tolerant clones. Some pubescent clones have been isolated for special attention taking advantage of the successful use of this physical characteristic in breeding for resistance to the green spider mite (Mononychellus tanajoa). The Root and Tuber Improvement Programme at IITA has also supplied PRONAM with over 120,000 seeds of wide genetic base. These, together with the seeds collected at M'vuazi have been planted at three locations in Bas-Zaire (M'vuazi, Kimpese and Boko) for screening for resistance to P. manihoti.

Summary :

More detailed information on many aspects of the Biology of the cassava mealybug will be given by the Entomologists. However, preliminary observations made so far tend to suggest the following :

1. From field observations, some cultural control measures suggested include (a) erosion control (b) elimination of brush fires (c) incorporation of organic matter in the soil and/or its utilization as mulching material. Any measure used to conserve soil moisture should be encouraged.

2. There is a tendency for mealybug severity to increase with drought. It is thus a severe dry season pest and breeding for resistance should take cognisance of confounding effects of drought.

3. Under fertile conditions with high water table, no reduction in root yield was observed. It must be emphasized that this observation is location specific and since no symptomless clones were obtained, the comparison is based on relative performance of many heterozygous clones. In highly eroded infertile soils lacking soil moisture, yield distribution of clones is skewed in favour of low yielding ones.

4. Though no data is available on exact magnitude of leaf yield reduction, completely defoliated manioc fields resulting from mealybug attack have been observed in Bas-Zaire.

5. To determine the effectiveness of cutting treatment with malathion on mealybug severity and incidence in areas where the pest has been observed, mealybug infestation should be critically evaluated. Whether cuttings are treated or untreated, mealybug infestation is readily observed on new foliage during periods of moisture stress. No differences in root yield were observed between treated and untreated plots.

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PRELIMINARY OBSERVATIONS ON THE MEALYBUG (HEMIPTERA PSEUDOCOCCIDAE) IN ZAIRE AND A PROJECTED OUTLINE FOR SUBSEQUENT WORK.

K. Leuschner
International Institute of Tropical Agriculture,
Ibadan, Nigeria.

Until 1970, when the mealybug was observed around Kimpese, white-flies and spidermites were the only Cassava pests of importance in Zaire. Since its first sighting, the mealybug has also been reported in Bas-Zaire and Bandundu. Outside Zaire there are definite reports from Congo Brazzaville and it has almost certainly reached North of Angola.

After the visit of Prof. Schaefers, Cornell University, samples of the insect were sent for identification to the Commonwealth Institute of Entomology who reported that the pest is an undescribed species of the family Pseudococcidae. Concurrently the same species was detected on Cassava in Brazil and samples sent to the Institute This strongly suggests that we are dealing with a newly introduced species, a view supported by its rapid progress such as occurs when an insect is not part of an established ecosystem.

Host parts attacked and damage

The mealybug initially attacks the terminal ends of cassava shoots, settling petioles and expanded leaves. The damage to the plant results from sapsucking and possibly by the introduction of an unidentified toxin with the saliva, causing stunting of the shoot.

Further symptoms are short internodes, little new leaf growth and curling of leaves. Eventually with increasing population density all green parts of the damaged shoot die, and die-back may or may not occur. Alternative infestation of lower leaves together with natural leaf fall during the dry season causes the so-called "candle stick" appearance of the cassava.

Economic damage

The economic damage to cassava caused by the mealybug is partitioned into loss of fresh leaves which are eaten as "pondu" and tuber yield loss. There is a definite loss of fresh leaves since the shoots which are normally plucked are infested, but the extent of tuber yield loss is still unknown. There is strong evidence that the age of the plant at the time of heavy attack and soil type are very important in relation to tuber yield loss.

Life history

Little is known of the life of the mealybug. What I present here is based on preliminary experiments observations and literature.

The female is parthenogenetic. The first instar larvae (so-called crawlers) are important for the spread of the pest. No males have been observed so far. The development period from egg to adult depends mainly on temperature and may be between 20 and 30 days. Counts of egg masses gave figures of between 200 and 400 eggs per female. The number of generations per year may vary in different regions according to climatic conditions. Studies of the climatic data of the last 15 years available in M'vuazi gave evidence that temperature, humidity and rainfall are the principal factors controlling development. In Fig.1 the monthly means of temperature, rel. humidity, VPD, windspeed and rainfall are graphed together with an assumed population development of the mealybug. The latter is only based on observations by Dr. Ezumah over the last 2 years and during my last two visits and illustrates the hypothetical situation over one year.

The most obvious conclusion is that the dry season favours mealybug population building up. Up to July the development is relatively slow, probably because of low temperature, low VPD and residual moisture in the soil which are necessary for plant growth. Increasing drought stress and change in temperature seem to favour the build up of the population. Particular interest should be paid to possible developmental stages of the insect adapted to overcome unfavorable conditions, such as the rainy season when it is seldom found. These could be dormant eggs, larvae or adults. Up till now no such postulated stages have been found. An alternative possibility is that a small proportion of the population always survives active but undetected on the plants.

Dispersal

There are two principal ways by which the mealybugs are spread: by passive transport on infested planting material and as unsettled first instar nymphs (crawler) which become airborne.

Infested planting material was probably the way the mealybug entered Zaire and is possibly the major reason for spread over far and short distances. Close observations on mature stems which could be used as planting material indicated that first instars are frequently found on newly sprouting buds. They were less frequently found on dormant buds. This gives an indication that planting material which has just started to sprouting is more likely to carry mealybugs than truly dormant material. In any case it is good agronomic practice to use material with dormant buds.

The second way mealybugs are dispersed is by wind. It was observed that only first instars (crawlers) became airborne. Close observations on the crawlers behaviour showed that they hatch mostly in the morning.

After hatching, a perhaps positive phototactic behaviour makes them move to the upper leaves and tips of the plant and thus exposes them to wind. These restless movements continue until about 12 o'clock. A subsequent study of the wind shows a steadily increasing windspeed from 6 to 12 noon. At 10 o'clock the wind mostly reaches a speed higher than 2km/h which seems to be enough to make many crawlers airborne. The question of how far crawlers can travel by wind was also subjected to a preliminary study. Four sticky traps (petridishes) were placed at 2, 15, 25 and 35 m distance from the source of infection. The height of the traps were 170 and 120 cm. After

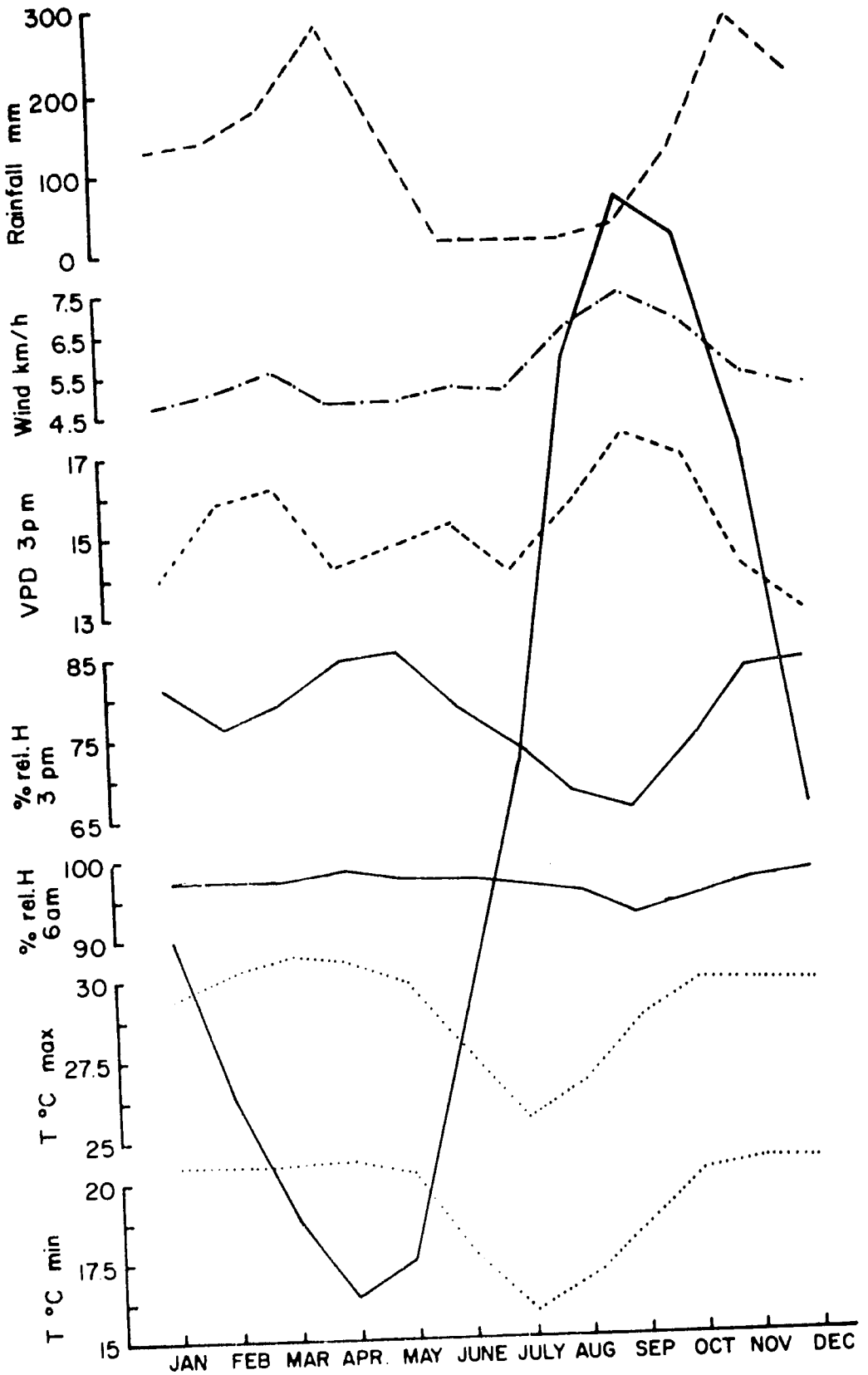

Fig. 1. PROJECTED MEALYBUG POPULATION DEVELOPMENT IN RELATION TO ENVIRONMENTAL FACTORS.

3 days the first trap caught 100, the second 7, the third 2 and the fourth none. No equipment was available to measure windspeed.

Based on this experiment and literature, it can be assumed that air-borne crawlers are mainly responsible for effective short distance spread. There are also indications that strong winds can carry them over much longer distances. This is supported by the following experiment. Sticky traps were placee 20 meters from the nearest source of infection at 1, 2, 3 and 4 meter height and over a period of 3 days, 6, 8, 5 and 9 crawlers were caught in 1 to 4 meter height. Presumably crawlers will generally fly longer distances at a height of 4 meters than at 2 meters.

Since from Bas-Zaire to Bandundu the wind-direction is mainly west-wards during the dry season, the mealybug infection front might slowly proceed in this direction even without dispersal by infected planting material.

Parasites

I mentioned previously that the success of the mealybug in Zaire is due to the fact that it is not part of an established ecosystem. This view is supported by the observation that only few unidentified parasites and predators of importance could be found during the period of my study. Although parasitism is only one of the constraints keeping insect pests within certain population density levels, this factor can be an important aspect of control.

Alternative host plants

Several unidentified weed species were found in cassava fields carrying mealybugs. In the short time of this study it could not be established whether development and reproduction takes place on them or not.

I got the impression that some of them served only temporarily as hostplants because only individuals were found and not colonies.

Projections for future work

With these preliminary observations, it is possible to make proposals for future work. Four different approaches to handle the problem may be projected:

1) Breeding for resistance

2) Biological control

3) Cultural methods

4) Chemical control

Breeding for resistance and biological control may serve as long term solutions while cultural practices and chemical control might be the short term answer.

Breeding for resistance

Breeding for resistance will probably be the best solution but it takes time. Investigation of the material present in Zaire both from INERA and IITA gives the impression that our germplasm base is not sufficiently large, although not all of the material has been exposed to mealybug attack. Therefore future steps taken by the Entomologist should be systematic exposure of the available material to find appropriate screening methods. If necessary introduction of more germplasm through IITA should be planned.

Biological control

As soon as feasible the entomologist should make contact with institutions like the Commonwealth Institute of Biological Control in order to survey the range of parasites and predators in this country and if necessary consider the introduction of species from the source of origin of the pest. As this involves predominantly entomological studies, a post doctoral fellow might be appropriate for this type of work.

Cultural methods

This type of approach seems to be the most promising short term way of finding an adequate method to reduce the problem in the near future. Investigation should be based on:

a) planting time

b) soil moisture conservation and other agricultural practices to improve plant growth

c) mixed cropping

Observations carried out by Dr. Ezumah indicate that planting around November results in less tuber yield loss. This observation is supported by comparison of climatological data and population development of the mealybug. (See Fig.1). By the time the mealybug population has built up the cassava is already between 9 and 11 months old if planted early in October. It was also observed that plants on soils with higher water table are more tolerant to infestation. Improvement of physical and mineral fertility could reduce the impact of the mealybug by strengthening the plant. Observations of dispersal by wind suggest the utility of mixed cropping as an additional means of restricting spread. The second crop should be a windbreak crop.

Chemical control

Chemical control of mealybugs should not be emphasised in the present stage although some chemicals should be screened for their effectiveness against the insect to have some information if needed.

Insecticides should only be used for dipping cuttings in order to reduce the spread of the pest in the country. An additional use of insecticides on an experimental basis would permit the critical establishment of yield loss.

BIOLOGY OF THE CASSAVA MEALYBUG, PHENACOCCUS MANIHOTI MAT.-FERR IN THE REPUBLIC OF ZAIRE

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ABSTRACT

The occurrence of the Cassava mealybug, Phenacoccus sp. in Zaire is reported. Data on its biology : oviposition, female fecundity and nymphal development are presented. Most of the insects settle on the leaf mid-rib and secondary veins of leaves and the growing points of cassava. The first instar nymph (crawler) is very important in the spread and survival of the species, the latter being within dormant leaf bugs during the wet season. Treatment of cuttings with an appropriate insecticide before planting, planting time and soil moisture conservation may aid in reducing damage to the crop. The occurrence of Spalgis limolea, Druce a predator of the pest is also reported.

INTRODUCTION

Cassava (manioc) (Manihot esculenta, Crantz) is a staple food in most of tropical Africa and Zaire is the third largest world producer next to Brazil and Indonesia. In Zaire both leaves and tubers are consumed. A few years ago with the appearance of the cassava mealybug, Phenacoccus manihoti Mat.-Ferr. coupled with other diseases, namely Cassava bacterial blight, cassava mosaic disease and anthracnose, the level of production has dropped thus considerably inflating market prices of cassava products.

The species of Phenacoccus attacking cassava in Zaire was only recently described by D. Matile-Ferrero (1977) as Phenacoccus manihoti, Mat.-Ferr. Apart from this report little is known about the cassava mealybug.

The study reported here is the first in a series designed at understanding the biology and bionomics of this pest as a step towards developing a sound and reliable pest management strategy for controlling the cassava mealybug. Laboratory experiments at the INERA Station, M'vuazi, Bas-Zaire and field observations in Bas-Zaire where the pest is presently most serious were conducted.

METHODS

Cultures of P. manihoti were maintained on cassava cuttings var. "Mpelo-longi" which were grown in polythene bags (12 x 10 cm) containing regular field soil. Plants were watered regularly thrice a week. No attempts were made to control temperature or humidity. However all tests were conducted in the laboratory with 4 - 6 week - old plants except where stated otherwise.

Biological records were made between 08.00 and 10.00 each day. Oviposition was determined by confining 25 adult females which had just molted into this stage each on a single plant; daily removing each egg mass when oviposition started and subsequently counting numbers of eggs under a binocular microscope. This was continued until all 25 females had died to obtain

adult female survival curve. Similarly mean incubation period was determined using eggs laid on the same day and observing numbers of eggs which hatched on the same day.

On a set of 4 plants one adult female was introduced on each fully expanded leaf of each plant and allowed to oviposit. On the first day of appearance of first instar nymphs on any plant all egg masses and females were removed. In this way nymphs were not handled and development period was recorded from egg hatch until the day adult females were first observed to commence production of wooly egg mass. The exact timing of successive instars was done by observing the appearance of cast skins and pre-eviposition period determined by recording dates of last molt and appearance of wooly mass.

Distribution of Phenacoccus on cassava was studied by confining egg producing females on ten cassava plants Ten days after infestation by which time crawlers were already observed, adult females and egg masses were removed and after another 6 days, allowing for settling of the last emerging crawlers, the distribution of the mealybug on the plants was recorded. Growing points were cut off and the tiny leaves separated to facilitate counting. A longer period of oviposition was discouraged to prevent overcrowding of insects and consequent masking of initial preference for plant parts.

Insect stage and method of hibernation were determined by planting 45 cuttings from a previously heavily infested cassava farm which at the time of this study (April) had no visible signs of mealybug infestation. After 5, 10, 15, 20 & 56 days the cuttings or plants were examined for the incidence of mealybug. Soil samples from the same area were also examined. In another test 48 cuttings and soil from the same field were subjected to the following treatments :

(1) Cuttings dipped in Rogor (dimethoate) solution 5 ml/l of water of a 500 g. a.i. formulation for 5 min., allowed to drain and dry in the sun for 5 hours and then planted in unsterilized soil in plastic bags.

(2) Treated cuttings as in (1) planted in sterilized soil.

(3) Untreated cuttings planted in sterilized soil.

(4) Control : Untreated cuttings planted in unsterilized soil.

Similar observations were also made after 5, 10, 15, 20 & 56 days.

RESULTS AND OBSERVATIONS

Oviposition

No males have been observed both in field and laboratory populations and females are parthenogenetic. Eggs are enclosed in an ovisac of felted waxen threads otherwise known as the "wooly mass" or "cottony mass".

At commencement of oviposition a thin wad of wooly mass is first produced into which the initial set of eggs are deposited. Production of the wooly substance continues with oviposition. During oviposition the body

of the mature female is seen to undergo rythmic contractions as eggs are voided into the ovisac. Eggs closest to the ovipositor are consequently younger than those furthest away. Newly laid eggs are almost glossy white but with incubation turn creamy and dark yellow to orange brown before eclosion. Older eggs furthest from the ovipositor may also be distinguished by two reddish brown spots representing eyes of the first instar which usually emerges a few days later.

Fecundity and Development

The oblong eggs measuring 0.3 - 0.75 mm in length and 0.15 - 0.30 in breadth are laid mostly on the growing point and the leaf under-surface but may also be found on the upper surface and leaf petiole and other parts of the plant. An average of 17.64(3-62) eggs per female are laid per day during an average adult life span of 20.2 days(6-26) reaching a maximum on the 7th day with an average of 37.43 (15-62) eggs per female (Fig.1). By the 7th day 43.56% of the total eggs are laid and only 24.4% are deposited in the second half of its life span. On the average the adult female lays a total of 440.89 eggs (210-715) during its life span. Such a range in this study may be attributed to physiological differences in fecundity between individuals. However when random egg masses are counted from field or laboratory samples, the differences are not only physiological but also due to differences in age of egg masses. Such counts do not reflect exact female oviposition capacity. In a trial conducted in which 25 egg masses were selected at random in the laboratory, an average of 140 eggs per egg mass with a range of 56-389 was observed. Average incubation period was 8.0 days (Table 1) thus in any egg mass examined only eggs that are 7 days or younger can be observed. This situation was avoided in our studies by making daily egg counts.

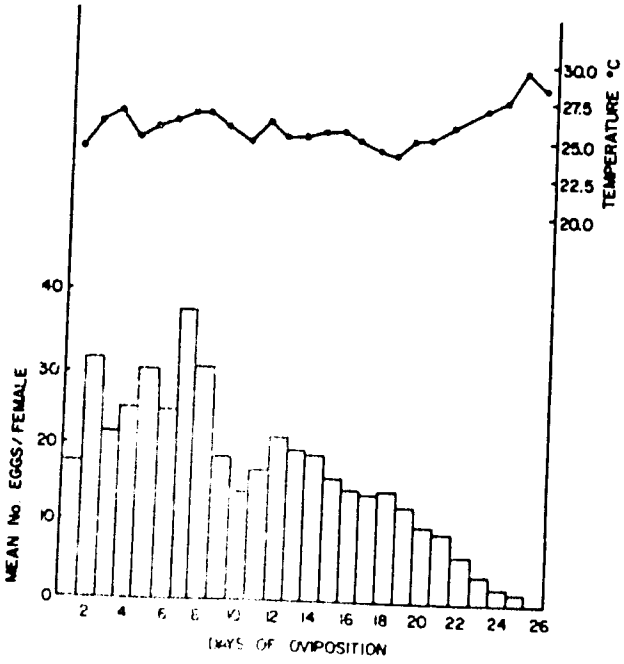

Fig. 1. Rate of Oviposition *Phenacoccus* sp. on Cassava.

On hatching, the egg shell is indistinguishable from the wooly mass. Newly hatched crawlers may remain sequestered for a time within the wooly material, thus hatching from eggs to emergence of crawlers from within the ovisac may be from a few minutes to several hours, and prolonged delayed emergence may result in mortality of crawlers within the wooly ovisac.

Table 1

DEVELOPMENT OF FEMALE CASSAVA MEALYBUG (*Phenacoccus* sp.) IN THE LABORATORY *

DEVELOPMENTAL STAGE	LONGEVITY (Days)		SIZE (mm) LENGTH		BREADTH	
Egg	8.0	(7 - 9)[1]	0.44	(0.3-0.75)	0.21	(.15-.30)
First instar(crawler)	4.5	(4 - 5)	0.60	(0.4-. 75)	0.25	(. 2-.30)
Second "	4.1	(3 - 5)	1.03	(1.0-1.1)	0.50	(. 5-.65)
Third "	4.2	(3 - 5)	1.50	(1.1-1.5)	0.55	(. 5-.60)
Fourth[2] "	5.2	(4 - 6)	2.00	(1.1-2.6)	1.00	(. 5-1.4)
Mature adult[3]	20.2	(6 -26)	2.57	(2.0-3.0)	1.43	(1.0-1.75)

* Mean daily laboratory temperature was 25.9°C

1. Range given in brackets
2. The 4th instar is the adult mealybug. Longevity represents pre-oviposition period
3. Longevity represents period from commencement of oviposition to mortality of mature adult female.

After hatching, probably due to a positive phototactic behaviour crawlers move to the upper leaves and tips of the plant thus becoming exposed to the wind. Greathead (1971) made similar observations on the sugar cane scale, *Aulacaspis tegalensis* (Zhnt). These movements continue during most of the morning hours as wind speed steadily increasing. Other instar stages are immobile for the greater part of their life, moving only a few millimeters away from the white, dot-like cast skin after moulting. On emergence from the egg and at subsequent moults insects are creamy white but soon become covered with a thin layer of white wooly substance.

The durations of nymphal stages at 25.9°C are given in Table 1. There are three moults and the 4th instar is the adult mealybug. Development in size is most pronounced between the third instar and the mature adult. With a mean adult life span of 20.22 days, short development period, parthenogenetic reproduction and high fecundity, overlapping of populations between generations of different females and within subsequent generations of the same female contributes to the rapid build up of populations of this pest under favorable conditions.

Usually mature adult females die 1-3 days after egg production is arrested by which time insects have shrunk to about half their original size at maturity. A comparison between oviposition rate (Fig.1) and female survival rate (Fig.2) indicates that the sharp decline in oviposition from the 9th day is not due to female mortality but natural physiological factors.

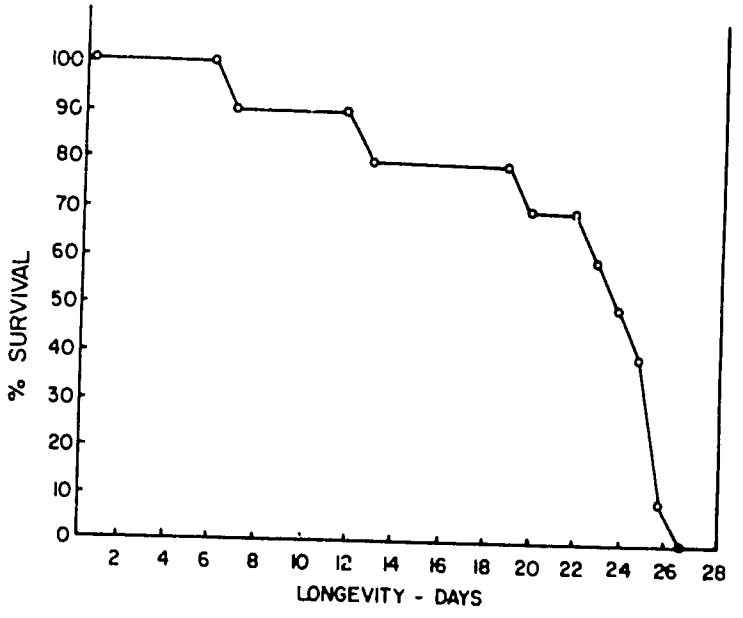

Fig. 2. Cassava Mealy bug: Adult Female Longevity

Distribution on hostplant

There is a preference for the undersurface of fully expanded leaves. Of a total of 1503 insects on 10 cassava plants 60.21% settled on the leaf undersurface and 27.48% on the growing point (Fig.3a). Only 1.33% settled on leaf petioles and 7.78% on the upper surface of the leaf. However orientation of the insects on the leaf showed a predilection for the midrib with 51.86% on this part of the leaf, 40.32% on the secondary veins, 10.21% on the leaf blade and only 1.59% on the petiole and leaf junction. Westigard (1964) in his observation of 714 insects of the grape mealybug on pear found a closely similar distribution.

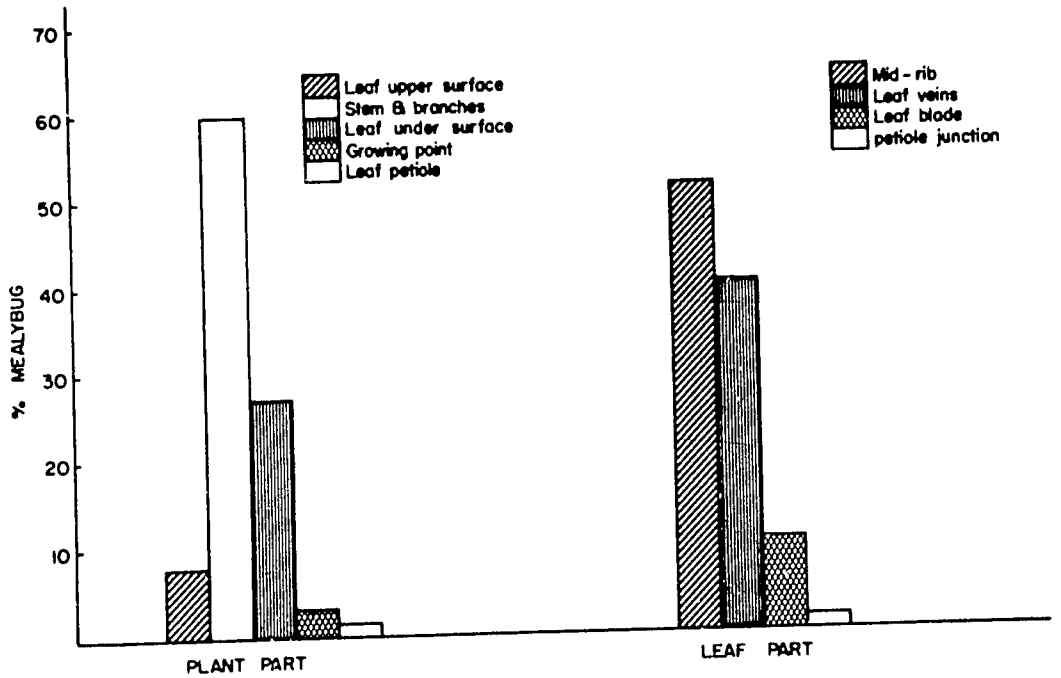

Fig.3a. Distribution of Cassava Mealybug on Cassava Plant.

b. Distribution of Cassava Mealybug on Cassava Leaves.

Although there were considerably more insects on the undersurface of expanded leaves, there were more insects per unit surface area on the growing point. A total of 120 expanded leaves were examined compared to 10 growing points. Usually damage symptoms appear first on the growing point as a bunched-top. There is certainly a search for abundant cell sap and this is confirmed by the orientation of the insects along the vessels. Closer examination by gently displacing insects showed that the thread-like stylet travels almost parallel to the leaf surface with the tip embeded within the midrib or secondary veins.

Hibernation and Spread

It was observed that planting material contained first instars, frequently sequestered on newly sprouting buds. Five days after planting, one plant out of the 45 cuttings had 3 crawlers on a leaf bud, the number increasing on the 20th day to 18 plants with 58 insects mostly crawlers and second instar nymphs. Crawlers are thus very important in the survival of this insect in dormant leaf buds during the unfavorable rainy season.

Survival of the cassava mealybug in cuttings was confirmed by the insecticide treatment trial. One control plant (unsterilized soil and treated cuttings) had one crawler and one second instar nymph 10 days after planting while in treatment no.3 (sterilized soil, cuttings untreated) two crawlers were observed (Table 2). No insects were observed in both treatments where cuttings were dipped in dimethoate. Six weeks later populations of mealybug had increased in the control treatment to 287 insects, 246 in treatment no.3 and no insects in treatment no.1 (soil unsterilized cuttings treated). However in treatment no.2 (Soil sterilized, cuttings treated) 26 insects were observed, the first being noticed only 32 days after planting. It is suspected that infestation of this treatment could be due to a drift from the neighbouring control treatment which was in the windward direction.

Table 2

Effect of treatment of cassava cuttings on the incidence of the cassava mealybug.

TREATMENT	Incidence of cassava mealybug				
	No. days after planting				
	5	10	15	20	56
Cuttings treated,[1] soil sterilized	-	-	-	-	-
Cuttings treated, soil unsterilized	-	-	-	-	26
Cuttings untreated, soil sterilized	-	2	9	11	246
Cuttings untreated, soil unsterilized (control)	-	2	12	12	287

1) Rogor (dimethoate) Solution 500 g a.i., 5 ml/l of water.

In several observations cuttings which were left lying around in the laboratory were later found to possess wooly masses on leaf buds. I have obtained mealybug populations simply by using cuttings from the field and after 4 weeks subjecting the plants to a moisture stress of 7 days. Thereafter cultures are maintained by keeping the plants on a minimum water regime.

In observations so far, I have not found any stage of the insect in the soil during the rainy season. These tests show that within fields and between fields dispersal of the mealybug is achieved by wind (as reported by Leuschner) and long distance spread is enhanced by the movement of infested planting material. While the treatment of cuttings with appropriate insecticides may reduce mealybug infestation or per chance delay infestation, wind dispersal of crawlers will eventually result in heavy mealybug infestation.

Damage to hostplant

Initial infestation begins evenly on the plant with higher numbers of insects being found on the undersurface of leaves and growing point. First symptom to appear is the bunched-top of the terminal growing point which may occur in about 2 weeks after infestation. One egg producing female is sufficient to cause this symptom. Later as infestation progresses leaves senesce and fall, shoot may die and die-back may occur. Alternative infestation of lower leaves together with natural leaf fall may result in the so-called "candle-stick" appearance (as reported by Leuschner).

Attack on stems results in stunting of the shoot with highly reduced internodes which may be due to the introduction of a toxin. Younger plants are more severely damaged and may be killed during heavy infestations with very low regeneration percentage during the next rainy season. When newly sprouting leaf bunds on recently planted cuttings are attacked, growth is arrested and the plant dies. In addition to the direct effects of defoliation on yield and quality of cassava herbage, loss of leaf surface and injury to the growing points may produce indirect plant responses such as withdrawal of food reserves in tubers and consequent effect on tuber quality.

Plants growing in poor soils such as along slopes suffer more damage than those on valley soils with rich alluvial deposits. Damage to cassava plants occurs mainly during the dry season (May - September). Severity of damage increases with increase in mealybug population as the dry season progresses. Usually by July/August most cassava plants are totally defoliated. However, with the onset of rains usually in October, populations have been observed to drop considerably and within a month of rainfall, new leaves and shoots are abundant. But isolated populations of P.manihoti persist on cassava stands during the wet season and serve as initial inoculum during the beginning of the next dry season. Usually as soon as the bunched-top symptom appears this serves as a protective umbrella during the wet season. It was observed also that a short dry spell during the rainy season is sufficient to trigger development of dormant crawlers. This may also be influenced by changes in cell sap constitution and concentration which are also affected by changes in soil moisture regime. Population build up and spread are however prevented by flushing rains during this period.

Parasites and Predators

So far only one predator, Spalgis limolea Druce (Lycaenidae, Lepidoptera), has been observed. Larvae of this lepidoptera actively feed on all stages of P. manihoti but mostly on crawlers. The larva camouflages itself by its slow movement and a covering of cottony substance thus looking like a giant mealybug - an observation also made by Nixon (1951). The pupa has a "monkey - face" appearance which may serve as a camouflage against members of the Formicidae which are known to tend mealybug. The success of this insect as an effective predator is currently being investigated.

CONCLUSION

The crawler of the cassava mealybug as in other mealybugs and scale insects is the primary dispersal phase as well as the hibernating stage. While a single gravid female may be all that is necessary to initiate infestation, crawlers are essential both for spread and dispersal and annual continuity of the population.

In the development of an effective pest management programme, we must take into consideration moisture conservation, planting time and use of mealybug-free planting material. While little or no value would accrue from screening pesticides for a full scale control of the pest since cassava leaves form a major part of the diet in Zaire, as a component of a pest management programme it will serve to limit spread of the pest by the use of clean planting material. The prospects of using S. limolea as an effective control mechanism are promising. But even with the introduction of a successful parasite or predator it still will be desirable to have a resistant variety because resistance would also enhance the effectiveness of the biological control agent by increasing the damage threshold and decreasing populations of the pest.

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CASSAVA MEALYBUG IN THE PEOPLE'S REFUBLIC OF CONGO

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Cassava, with numerous local and imported cultivars, is by far the most important food crop of the People's Republic of Congo (Fig. 1). In addition to the consumption of tubers, fresh leaves are used in the preparation of saka-saka or brete.

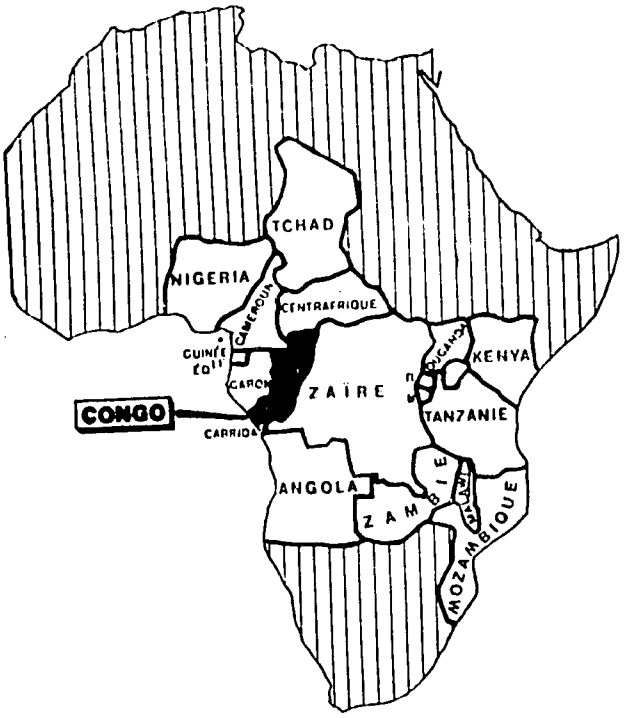

Fig. 1: The People's Republic of Congo

Out of a total of 147,750 ha of cultivated land (Bertrand 1975) some 53,000 ha is used for the production of cassava, a clear indication of the dominant role of the crop in the diet of the population.

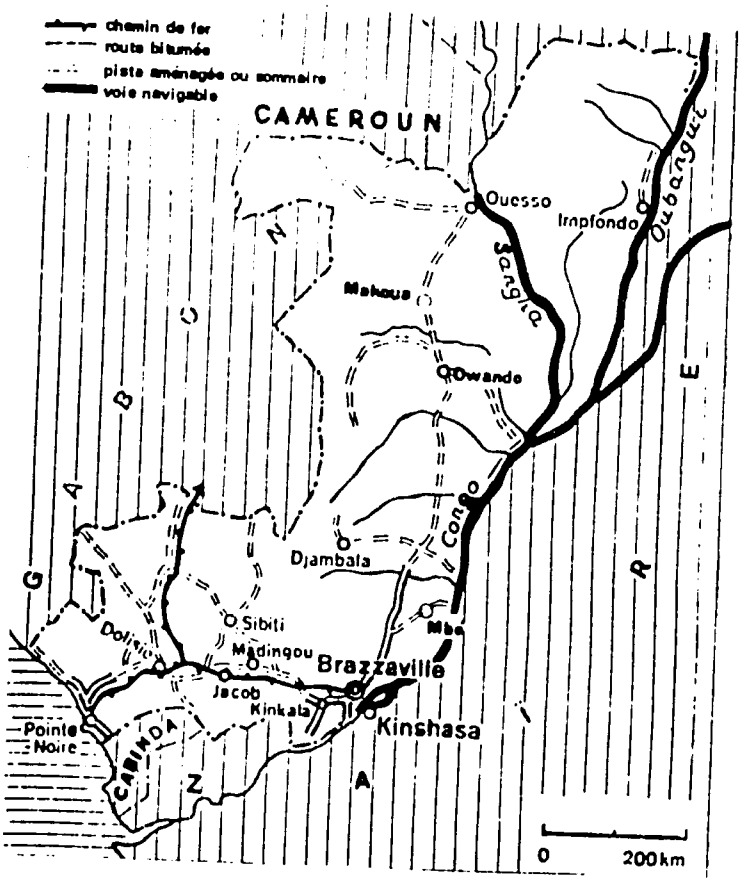

Fig. 2: Principal routes of communication

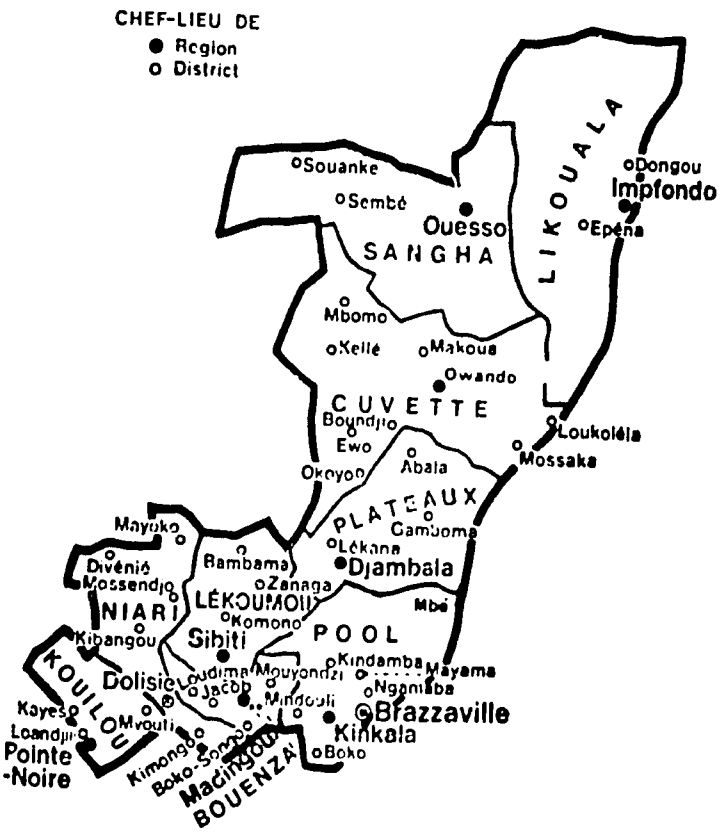

Fig. 3: People's Republic of the Congo; administrative structure

Cassava cultivation is primarily practiced by the small farmer in small scattered plots and the major areas of production are the Pool Region (Fig. 2) and along the Brazzaville-Pointe-Noire link (Fig. 3) because of their relatively high rural population density.

Since 1970 three agro-industrial cassava production units have been established by the Congolese Government at Makoua (Region de la Cuvette)-Mbe (Pool Region) and Mantsoumba (Madingou) in the Bouenza Region of the Niari valley. Of these the latter is the most important (Figs. 2 and 3). The Mantsoumba (Madingou) State farm: first agro-industrial cassava production unit.

1. Background

The Mantsoumba experimental farm, established at the end of 1970, is situated 220 km to the west of Brazzaville and covers 3,900 ha of land previously devoted to cattle rearing. Between 1972 and 1975, about 1,500 ha have been planted to cassava, maize and Stylosanthes gracilis (Leguminosaceae) of which 800 ha were under cassava.

The initial objective of the farm was to define technically and economically appropriate methods for mechanized cassava production on an industrial scale by experiment and economic production analysis. Unfortunately, the sudden appearance of the mealybug Phenacoccus manihoti Mat-Ferr, in the spring of 1973 has considerably hindered these trials. Agronomic trials at Matsoumba were mainly concerned with the provision of quickly available information to assist in

- selection of the best adapted local variety
- optimising planting and harvesting dates
- developing appropriate cultural practices, particularly for weed control
- evaluating yield in relation to mineral nutrition
- exploring the suitability of maize for rotation cropping with cassava.

2. The Environment

The climate is hot and humid. Rainfall, which averages 1100-1200 mm per annum, begins sparsely in late September with 5-10 mm, becomes established in October and ends in May. Apart from September, the less rainy months are October, February and May with around 80 mm, the remaining wet season months receiving more than 150 mm, and in April, usually the wettest month, a mean of 250 mm rainfall has been recorded. June, July August and most of September are completely dry. Rainfall data for Madingou and Brazzaville are given below (Tables 1 & 2).

TABLE 1. RAINFALL AT MADINGOU

MONTHS	Years 48 - 52		52-59	62 - 63		63 - 64	
	mm.	nbj.	mm.	mm.	nbj.	mm.	nbj.
Sept.	2.6	0,3	12	7.	2	4.4	3
Oct.	105.1	6,5	92	83.9	9	167.6	7
Nov.	206.4	12,2	185	141.2	8	223.8	11
Dec.	203.3	11,5	184	217.8	13	141.9	11
Jan.	106.7	7	107	213.4	15	178.7	8
Feb.	153.7	10,3	79	59.1	8	116.4	12
March	209.8	9,3	169	183.7	17	173.7	16
April	218.9	10,6	250	170.3	14	313.5	21
May	114.5	7,3	106	19.1	7	196.1	11
Total	1,332.	78,6	1,184				

MONTHS	Years 64 - 65		65 - 66		66 - 67		67 - 68	
	mm.	nbj.	mm.	nbj.	mm.	nbj.	mm.	nbj.
Sept.	-	-	8.	3	11.2	3	1.1	1
Oct.	65.9	6	76.1	6	62.8	5	74.1	6
Nov.	220.2	17	54.2	15	333.4	23	186.	16
Dec.	377.6	22	62.4	9	147.7	16	123.	7
Jan.	104.5	9	186.4	14	146.3	10	123.9	12
Feb.	86.8	11	97.7	13	74.6	9	122.2	10
March	216.5	10	280.3	12	265.5	14	114.3	12
April	224.3	17	365.3	17	56.8	6	216.0	14
May	-	-	197.5	8	218.4	8	91.6	10
June	-	-	8.1	2	39.7	3	-	-
Total			1,336.5		1,356.4		1,052.2	

TABLE 2. RAINFALL AT BRAZZAVILLE (ORSTOM)

YEAR	J	F	M	A	M	J	J	A	S	O	N	D	Total
1968			186,6	235,9	123,2	0	0	0	27,5	80,9	142,6	42,6	1222,7
			14	16	13	0	0	0	10	9	20	9	91
1969	106,8	79,6	115,0	349,1	245,4	1,1	0,7	0	12,4	109,9	291,1	218,9	1530
	11	6	19	18	11	1	1	0	3	8	19	14	111
1970	92,0	114,2	231,0	318,0	98,2	0	4,1	0	31,8	96,7	394,6	116,7	1497,3
	9	12	15	15	8	0	2	0	3	5	17	8	94
1971	141,6	50,8	128,5	128,4	78,0	8,6	1,2	0,2	23,3	194,1	133,4	203,2	1091,3
	5	5	10	11	7	1	2	1	7	10	17	11	87
1972	126,7	13,4	94,9	125,5	61,4	0	0	20,6	5,2	103,9	388,6	98,1	1048,3
	11	6	10	11	9	0	0	2	4	6	15	14	88
1973													
1974	314,1	117,8	167,0	220,6	96,0	0	0	0,5	3,5	138,5	253,2	182,8	1494
	14	12	10	12	7	0	0	1	3	17	14	13	103
1975	103,2	153,4	221,1	160,9	155,4	7,4	0	0	5,8	166,4	280,9		1254,5
	12	8	12	13	12	2	0	0	4	7	17		87+dec.

The farm is situated in two major soil types: clay (53-55% clay in the top 15 cm) and sandy clay (30-40% in the top 20 cm) of which the latter is the predominant type under cultivation. Neither possesses a concretionary layer within the top 2 m.

Various studies on the soils of the Niari Valley (ORSTOM, 1967) have shown that under savannah vegetation the upper soil horizons contain 3-4% organic matter and at least half of the low cation exchange capacity is due to the colloidal fraction of this organic matter. With cultivation the humus content is lowered and the capacity to retain mineral ions is reduced to a few milli-equivalents per 100 g of soil. Levels of exchangeable bases decrease rapidly with removal of nutrients in the form of harvested crops when no fertilizer is applied and losses also occur through leaching. The loss of exchangeable bases is faster than the reduction in capacity for mineral retention causing a drop in pH from 5 to 4.7 or 4.6 with the conversion of manganese to an exchangeable form resulting in toxicity problems.

3. Mealybugs: Initial observations

In 1973 Silvestre described the first mealybug attacks in Matsoumba as follows: "relatively important infestation of as yet unidentified mealybugs is observed on terminal buds. These are destroyed with the result that new buds are produced, only to be attacked in their turn. These infestations certainly contribute to the weakening of the plants though the extent of this is difficult to evaluate, and they may disappear with the arrival of the rains."

In 1975 the same author reported:

> "During two dry seasons of 1973 infestations of mealybugs on the terminal buds of cassava were reported which disappeared during the rains. In 1974 the infestations seemed more severe; increased cultivation of cassava may have favoured the pest though the higher level of attack may also have been associated with the greater severity of the dry season... Mealybug damage is spectacular at the end of the dry season and it would be useful to have an evaluation of the resulting crop loss .... The possibility of chemical control of these pests seems excluded for obvious economic reasons. On the other hand, biological control, which has already given excellent results in other countries, could be rapidly adopted if it proves that the pest continues to spread and cause considerable damage. Appendix 21 presents a report produced in collaboration with M. Breniere, Entomologist and Head of IRAT Division of Crop Protection (Paris), which gives data on the biology of P. citri and P. adenidum with a first evaluation of requirements for the establishment of biological control measures."

In 1976 Silvestre reported further:

> "Mealybugs observed during the 1973 dry season continued to spread in 1974 and it seems infestations in 1975 have been even more severe. The high likelihood of effects on the quality of cuttings by those infestations is noted above; unfortunately, no data on the effect of the pest on yield are yet available..."

Visit of the Paris Museum Coccidological Mission: October 1975
Following the intensification of mealybug attacks during the 1974-75 dry seasons, the author traveled to the People's Republic of the Congo in October 1975 in order to more precisely define the areas affected my mealybugs. During this trip it was possible to visit six of the nine administrative departments in the country.

1. La Bouenza: Matsoumba State Farm (Madingou); Loudima
2. La Cuvette: Makoua State Farm; Atekou
3. Le Kouilou: M'vouti; Pouenga, Dimonika and Makaba
4. Le Niari: Loubomo (formerly Dolisie)
5. Le Pool: Brazzaville; Linzolo region and Congo riversides; M'Bamou Island, Odziba and Kiani (Bakete plateaux); Kindamba; Mindouli
6. Les Plateaux: Djambala

Results: Levels of infestation in cassava fields (Fig. 4).

A. Insect-free fields

Fields from which the mealybug was absent were identified in various parts of the country. These were:

1. La Cuvette: No attack in this administrative Department
2. Les Plateaux: No attack
3. Le Pool: No attack observed in Kindamba (250 km North, West of Brazzaville), in Kiani (120 km North of Brazzaville).
4. Le Kouilou: No attack observed in distant villages of Pouenga, Dimonika and Makaba.

In Kiani and Pool the healthiest and most vigorous cassava was cbserved.

Fig. 4: ★ Cassava fields infested by Phenacoccus manihoti (Mat. Ferr)

□ Cassava field uninvaded by the mealybug in October 1975.

B. Affected fields

a) No mealybug infestation observed; in Djambala the cassava showed clear signs of withering. Almost complete dessication of the aerial plant parts was noted with no tuber formation. The situation was very serious in 1975.

b) Mealybug infested; actual areas of infestation closely follow th route of the single railway track, le CFCO (Chemin de Fer Congolais) connecting Brazzaville and Point Noire (515 km). Clearly this line of communication facilitates transportation and exchange of all types, as it also attracts high population concentrations, and almost half the country's population, including urban centres, is distributed along the route. Cassava fields adjacent to the railway are invaded by Phenacoccus manihoti and thus heavy attacks are observed at Bouenza from Loudima to Mantsoumba (Madingou) and Mindouli, at Pool, Brazzaville area, Linzolo, M'Bamou and in Niari, Louboumo (formerly Dolisie) and surroundings.

The degree of invasion is, on the other hand, much lower at Kouilou, in M'vouti, where small holdings exist in clearings within high tropical forest (Massif de Mayombe) and thus benefit from their presence in a less disturbed ecosystem.

The ants which are generally associated with colonies of Pseudococcids have only been observed on a few stands of cassava. In Mantsoumba, for example, the author observed only two cassava stands with specimens of Paratrechina sp., Camponotus sp. (Formicidae) and Crematogaster sp., Myrmicidae (1). At Linzolo (South of Brazzaville) in infested smallholdings, ants seemed more common than at Matsoumba and individuals of Crematogaster sp. (Myrmicidae) and Acantholepis sp. (Formicidae) were collected. Other mealybugs were observed on cassava in different parts of the country, always as small colonies or isolated individuals. Those were as follows:

- Pseudococcidae: Planococcus citri (Risso) and Ferrisia virgata (Ckll.)
- Coccidae: Saissetia nigra (Nieth) and S. oleae (Olivier)
- Diaspididae: Pinnaspis Strachani (Cooley)

c) Incidence of Aleurodids and phytophagous mites;

The aleurodid Bemisia tabaci (Germ) and the mite Oligonychus gossypii (Zacher) were common in most of the cassava plantations in the Republic of Congo, both in fields invaded and not invaded by Phenacoccus manihoti. Morphological and systematic study of Phenacoccus manihoti Matile-Ferrero, 1977 (Homoptera, Coccoidea, Pseudococcidae).

The original description and illustrations presented by the author (MATILE-FERRERO, 1977) are given below.

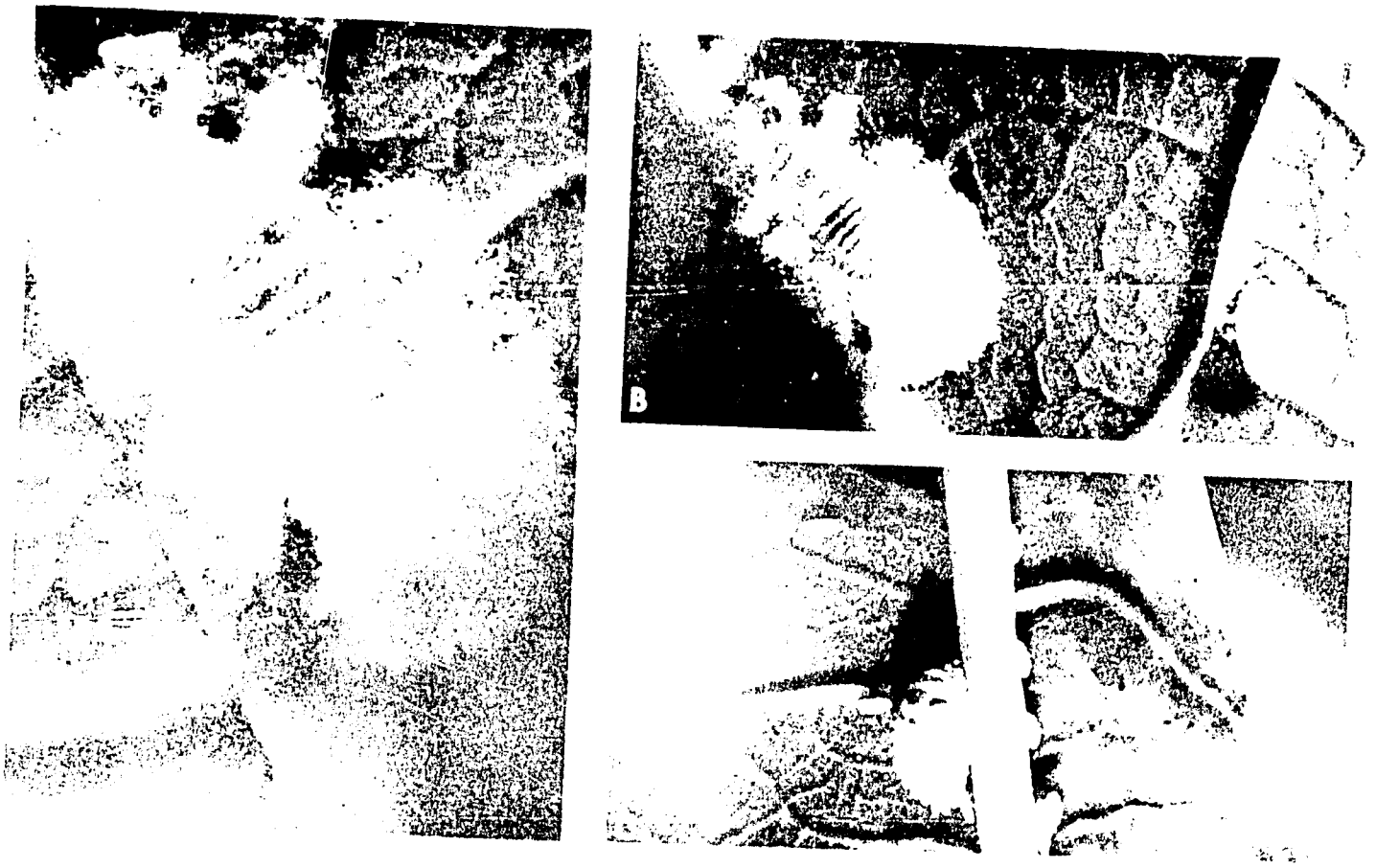

Fig. 5: Phenacoccus manihoti macroscopic form: A, ♀ adult; B adult and 3rd instar larva; C, adults prior to parturition and 1st instar larvae (Photos Miesch & Medard).

Morphological characteristics:

Adult: ovoid; rose-pink body, very slightly covered with white secretion, finely granular such that segmentation is apparent; marginal secretions corresponding to cerarii in the form of swellings which give a toothed appearance to the body outline (Fig. 5).

Ovisac slightly structured, broad, white and with cottony texture, laterally framing + but leaving dorsum uncovered and clearly visible in isolated specimens (Fig. 5, A and B).

Microscopic characteristics:

Adult (Fig. 6): L = 1 to 2.7 mm; long 9 segmented antennae corresponding to the following formula (3): 2,3,9, (5,), (7,8), (4, 6); prominent eyes, well-developed and equal sized legs; tarsal claws moderately narrow and elongate provided with an inner hook and fine processes, slightly spatulate at the apex (Fig. 6:7); circulus developed, elongate and laterally constricted giving the appearance of double headed yoke (Fig. 6:8); anal ring armed with 6 bristles, shorter than that of the anal lobe (Fig. 8:2); 2 pairs of dorsal ostioles with a few associated trilocular pores and some short and less scattered spines; 18 pairs of marginal cerarii (C_1 to C_{18}), each with 2 fusiform spines and 5 to 8 associated trilicular pores; a small cuticular spine is often found near these 2 spines and could be wrongly taken as the third spine of the cerarius: anal cerarius, C_{18} (Fig. 6:9) and pre-anal cerarius, C_{17} with markedly stronger spines. Cerarii of young females are protruding and mamilliform.

Ventral surface: anal lobe bristle and auxiliary anal bristle are normal (Fig. 6:2). Ventral pilosity with fine elongate bristles of varying lengths which disappear in favour of short fusiform spines resembling those on the dorsal surface. (Fig. 6:4). Anterior pilosity normal. Numerous small pentalocular glands decreasing laterally. Trilocular pores (Fig. 6:3) absent in median region, sparse in submarginal and marginal regions. Tubular pores are few with slightly varying sizes (Fig. 6:5), scattered all over the ventral side and transversally aligned on segments VI to VIII associated with multilocular glands. Numerous multilocular glands (Fig. 6:6), restricted to the lower part of abdominal segments lying behind the circulus. Few submarginal and marginal elements are found on V and VI and can be totally absent; some multilocular glands may be observed in the anterior part of these segments, mainly on segment VIII. Tiny and scattered discoidal micropores. Dorsal surface: covered with scattered small and fusiform spines of same or smaller size than those of the cerarii (Fig. 6:12).

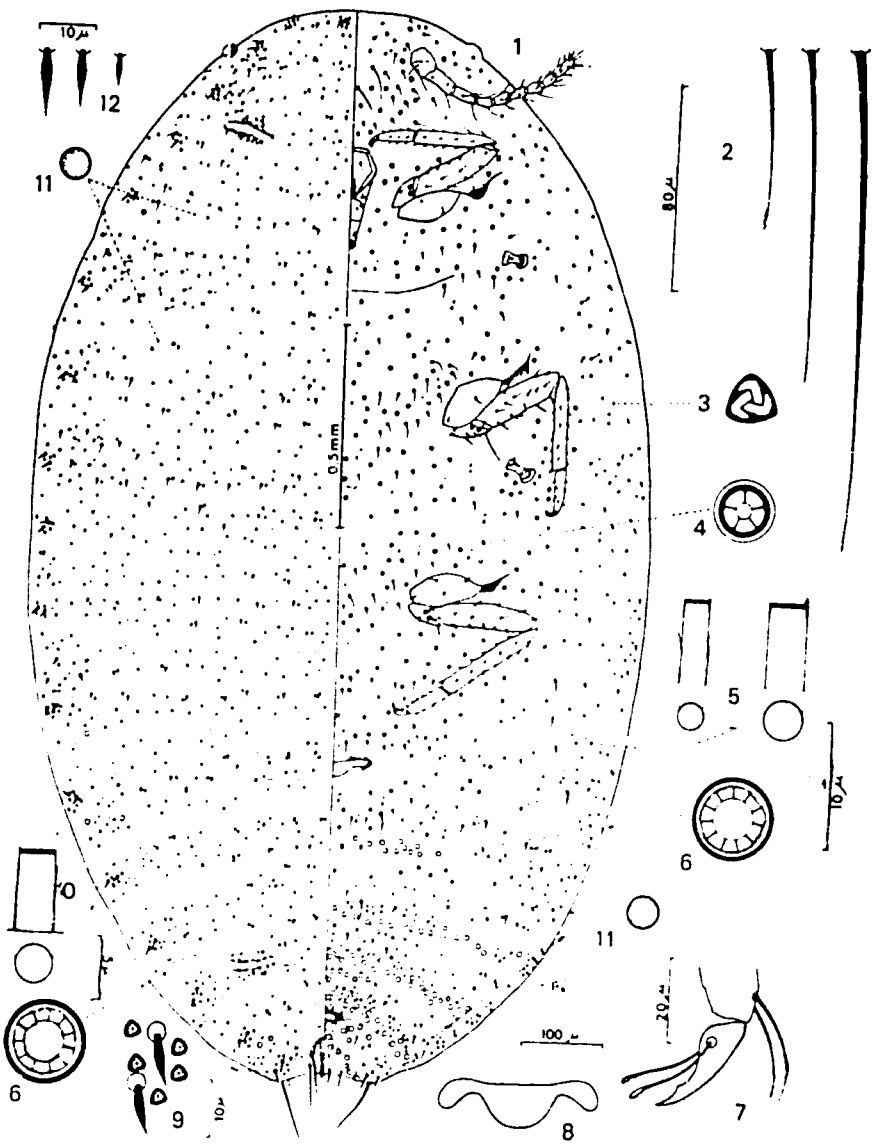

Fig. 6: 1 - 12 Phenacoccus manihoti, adult; 1. General diagram; 2. (from left to right) auxiliary anal bristle, anal ring bristle, anal bristle; 3. trilocular pore (ventral and dorsal); 4. ventral pentalocular gland; 5. ventral tubular pore (size variation); 6. multilocular gland (ventral and dorsal); 7. claw of posterior tarsus; 8. outline of ventral circulus; 9. detail of anal cerarius; 10. margino-dorsal tubular pore; 11. discoid micropore (ventral and dorsal); 12. 3 sizes or dorsal spines.

Regularly distributed trilocular pores. Near each cerarius, submarginal concentration of tubular pores (from 6 to 12), identical to those on the ventral surface with nearly the same diameter at the insertion point of the spines of the cerarii (Fig. 6:10). A few multicolor glands (Fig. 6) can be observed located submarginally near the cerarii. Their number and topography are not constant and the distribution of these glands is rarely symmetrical for a pair of cerarii (see remarks) (Fig. 8). Scattered discoidal micropores (Fig. 6:11).

Male: not observed. Of the numerous colonies examined in October-November no males were observed.

Third larval instar (Fig. 7:15 and 7, B): L = 0.85 to 1.30 mm; 9 segmented antennae; hook on the tarsal claw (Fig. 7:19, C); 18 pairs of cerarii, protruding laterally in young individuals; total absence of tubular pores; developed circulus (Fig. 7:16); ostioles present.

Ventral surface: pentalocular glands observed, uniformly distributed and sub-equal to those of previous phases: no trilocular pores in median and submedian regions; moderate pilosity (Fig. 7:22).

Dorsal surface: spines and trilocular pores uniformly distributed (Fig. 9:21). Second larval instar (Fig. 9:14) L = 0.60 to 0.79 mm 6 segmented antennae; hook on the tarsal claw (Fig. 7:19, b); clearly observable anal cerarius; other cecarii indistinct; no tubular pores except an anterior pair and one element near each of the anterior stigmata; developed circulus (Fig. 7:17); ostioles present.

Ventral surface: pentalocular glands observed virtually the same size as those of the other instars, distributed in transverse bands on abdominal segments and randomly on the rest of the body; no trilocular pores in median and submedian regions (Fig. 7:21); reduced pilosity.

Dorsal surface: spines accompanied by trilocular pores (Fig. 7:21) distributed in longitudinal bands. First larval instar (Fig. 7:13 and 7, C) L=0.40 to 0.60 mm, 6 segmented antennae, hook on the tarsal claw (Fig. 7:19, a); clearly observable anal cerarius; other cerarii not distinct; small tubular pore present at the base of each antennae; developed circulus, variable laterally digitate and often mammiliform in the center (Fig. 7:18); ostioles present.

Ventral surface: few pentalocular glands, roughly of the same size as the ones of the previous instars, distributed in 4 longitudinal bands; trilocular pores absent; reduced pilosity, elongate, clearly visible sclerotisation on the anal lobe.

Dorsal surface: spines accompanied by trilocular pores (Fig. 7:21) distributed in longitudinal bands.

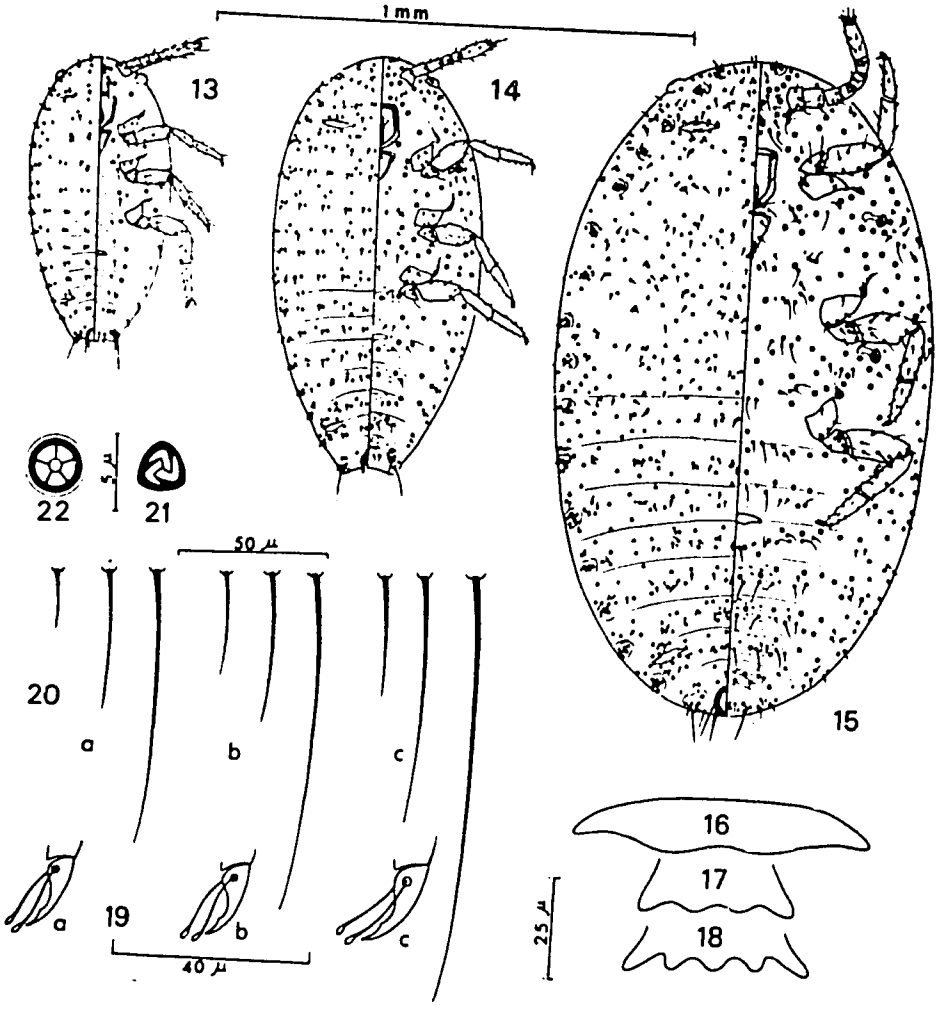

Fig. 7: 13 - 22. Phenacoccus manihoti; laval instars; 13. general diagram of 1st instar; 14. second instar; 15. 3rd instar; 16. outline of circulus, instar III; 17. instar II; 18. instar I; 19. tarsal claw; a instar I, b. II, C. III; 20. (from left to right) auxiliar anal, anal ring anal bristles a. instar I, b. II, c. III; 21. trilocular pore (common to all instars); 22. Pentalocular gland (common to all instars).

Remarks - The presence of multilocular glands in reduced numbers (exceptionally absent) on the dorsal surface and their irregular distribution make it difficult to identify Phenacoccus manihoti morphologically because of the glandular variability of the adult female. From a sample of 139 individuals collected from 8 different sites in the Republic of Congo the total number of dorsal glands was shown to range from 0 to 16 (average: 6.30), with only 2 females which had none. Two individuals from Zaire had 4 and 14 glands. Of 4 individuals from Brazil, 1 individual possessed 1 gland (left) in the region of cerarius C13 while the other 3 had none.

This sampling also showed that extreme variability in the topograph of these glands occurs among populations of the same area. Figure 8 represents, for 1000 individuals taken at random during harvest, the frequency of the presence of multilocular glands for each pair of cerarii (C11 to C17). For 40 of these individuals the variation was as follows:

- for C_{11}, from 0 to 2 glands on each side;
- for C_{12}, from 0 to 2; C_{13}, 0 to 3; C_{14}, 0 to 5; C_{15}, 0 to 4; C_{16}, 0 to 2; C_{17}, 0 to 3.

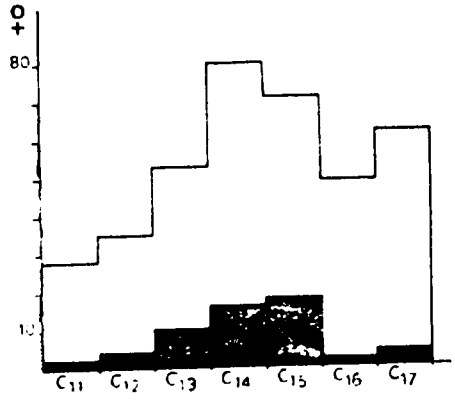

Fig. 8. Phenacoccus manihoti, frequency of individuals possessing dorsal multilocular glands in the region of cerarii C_{11}-C_{17}. Shaded; symmetrical individuals (n = 100).

Phenacoccus manihoti is very closely related to Phenacoccus eremicus FERRIS, 1950: the two species can be distinguished by the following characters:

- presence of tubular pores over the whole dorsal surface; ventral trilocular pores uniformly distributed; numerous multilocular dorsal glands (may sometimes be absent):

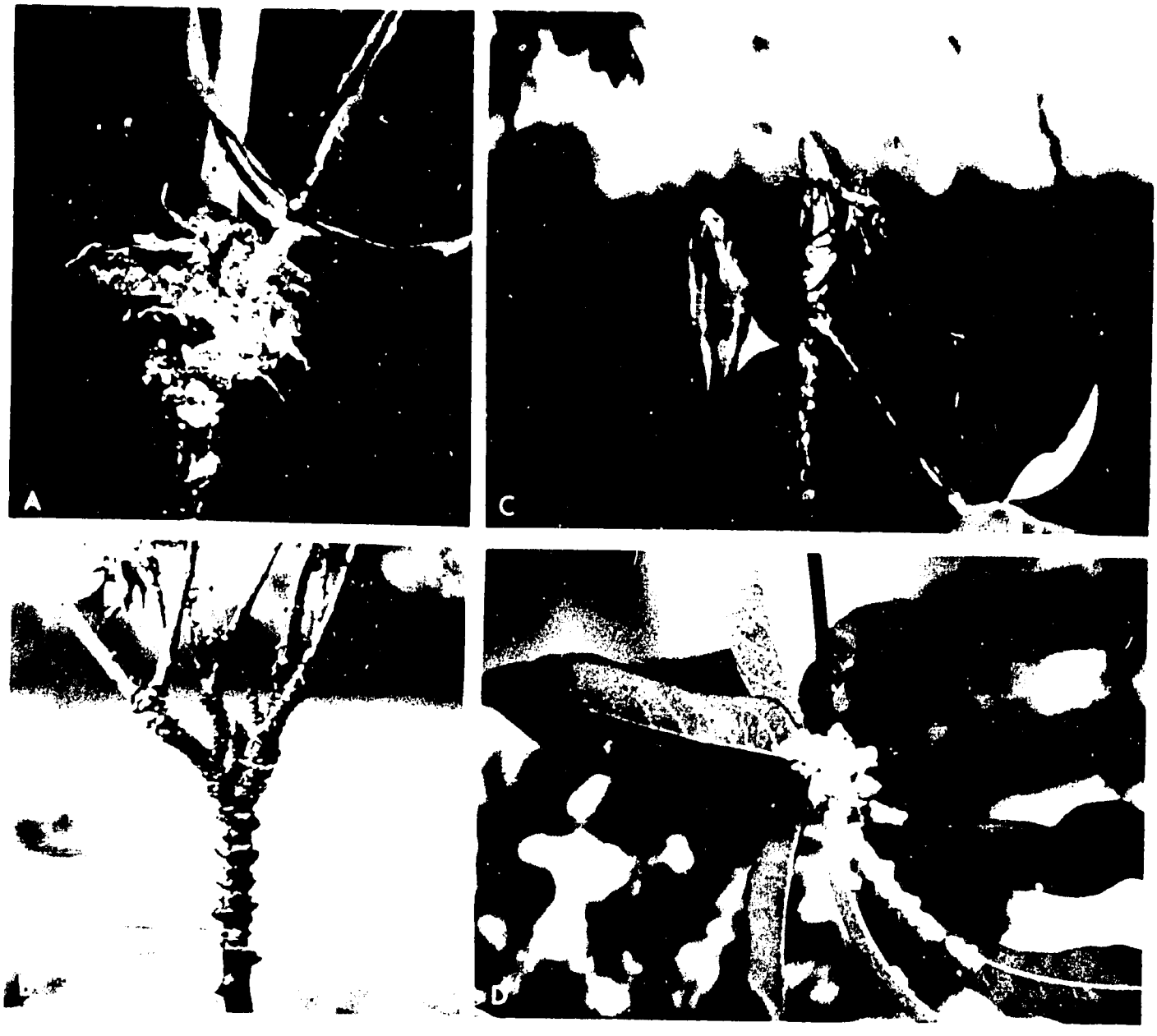

Fig. 9: Phenacoccus manihoti, damage: A; infested bud; B, stunting of internodes; C, Terminal bud with advanced infestation; D. fresh attack on expanding leaf.

Regularly avoid circulus: cribriform pores on the posterior tibia.. ..... eremicus FERRIS

- Dorsal tubular pores confined to marginal and submarginal regions:

Ventral trilocular pores absent from median to submedian regions. Dorsal multilocular glands reduced to a few submarginal elements (1 to 16), exceptionally absent; circulus elongate, laterally narrowed and resembling a double yoke (the same type as in Ph. gossypii TOWNSEND AND COCKERELL, 1898) no crobriform pores on the posterior tibia ..... manihoti n.sp.

Biology Habitat

Phenacoccus manihoti previously unknown, has suddenly become a serious pest of cassava fields in equatorial Africa, principally in Zaire and the People's Republic of Congo. It has also been reported from Gabon. Moreover, samples of Phenacoccus manihoti have been sent to us from Belem-Para, Brazil, though biological information is not yet available.

Phenacoccus manihoti particularly attacks terminal shoots, which become deformed and internode stunting follows (Fig. 9, A, B). The lower surface of expanded leaves is also invaded along the veins and this followed by rapid withering. First records of damage were reported by SILVERSTRE (1973) see (page 3).

Individuals of Phenacoccus manihoti have been found with their ovisac on weedy plants in a cassava field on M'bamou Island. It would, however, be premature to conclude that this species is polyphagous, these individuals having probably dropped on the soil by chance and produced their ovisac on the nearest available plant support without feeding.

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TAXONOMY OF MEALYBUGS ON CASSAVA

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Mealybugs are usually soft bodied insects with distinct segmentation. Although adult females may measure from 1-9mm long, a common length of most species is about 3-4mm. In shape they are elongate-oval and characteristically they are thinly covered with white mealy wax, but around the margins there is often a series of 1-18 short wax filaments, those at the margins there is often a series of 1-18 short wax filaments, those at the posterior end being often longer than the others. General totally without wax filaments are rare. Oviparous species usually secrete an ovisac of a cottony consistency around the posterior end of the body but sometimes the body is completely enclosed.

Mealybugs belong only to the family Pseudococcidae, one of about 12 families of scale insects of the superfamily Coccoidea. Of about 9,000 scale insects already described, 3,000 of them are mealybugs.

Characters separating the scale insects from all other Homoptera are the single claw, degenerate adult females, adult males with a single pair of delicate wings, and without mouthparts that are functional.

In common with all scale insects the females are neotenic, differing little in shape from the previous immature stages. The separation of the head, thorax and abdomen is indistinct. Many species are parthenogenetic always or for a part of the year. When males exist they pass through an extra stage. The first two male stages resemble those of the female but the insect then passes through two pupal stages before emerging as an adult. An adult male is usually winged, in which case the wings are represented by the first pair only. The second pair are much reduced and often hook on to the first pair. No functional mouthparts are present and the insect lives for only a day or two, although some have been reported to live for as many as 5 days. Occasionally males are degenerate and after passing through two pupal stages they revert to laviform characters.

Mealybugs may live on all parts of the plant. In bark crevices, at the bases of leaf petioles or on the roots, they become difficult to control. Waxy coverings afford some means of protection against contact insecticides, whilst eggs are protected by the ovisacs. Some of the organic phosphate insecticides have been used against mealybugs with varying success but their use is hazardous.

The anal ring may have numerous pores which secrete a short tube of wax held in place by the anal ring setae. Honeydew excreted through this tube is, therefore, kept a short distance from the body but it is sometimes ejected away from the mealybug. The excretions are rich in sugars and amino-acids, and, when palatable to ants, may form an important part of an ant's diet.

When the number of species is not too great on any one host it is possible to identify species in the field by the external appearance only, as the following key illustrates:

KEY TO EXTERNAL CHARACTERS OF MEALYBUGS ON CASSAVA IN WEST AFRICA

1) Caudal wax filaments at least half as long as body 2

-. Caudal wax filaments less than half body width 3

2) Wax filaments represented by caudal pair only, these half to three quarters body length. Dorsum covered with long glassy threads. With 2 dark sub-median stripes. (Zaire, Congo R., A.O.F., Togo, Sierra Leone, Ghana) .. Ferrisia virgata (Ckll.)

-. Wax filaments numbering 17 pairs, the caudal filaments about as long as body, the shortest marginal filaments equal to about half body width. No definite ovisac formed. Without dark sub-median stripes. (Zaire, San Thome, A.O.F., Togo) ..... Pseudococcus longispinus (Targ.)

3) Wax filaments numbering 17 pairs, moderately long. Ovisac small. (Zaire) ..... Dysmicoccus brevipes (Ckll.)

-. Wax filaments numbering 18 pairs, the lateral filaments short. Ovisac well developed .....4.

4) With a single median dorsal stripe. Body dull yellow. (Zaire, Congo R., A.O.F., Togo) ..... Planococcus citri (Risso)

-. Without median dorsal stripe 5

5) Body rose-pink. Ovisac short, wide and flaky (Zaire, Congo R., Gabon, Angola) ..... Phenacoccus manihoti M.-F.

-. Body pale green. Ovisac loose of irregular shape. (Nigeria) ..... Phenacoccus madeirensis Green

A.O.F. is used to represent the present Francophone countries when the exact locality has not been given.

Classification and identification of mealybugs is based mainly on the microspic characters of the adult female or fourth instar. This instar can be distinguished from all other instars by the presence of a vulva. A thorough study of the adult female can only be made from properly prepared specimens on microscope slides. This often requires expert technique and various methods are discussed by McKenzie (1967). Satisfactory results may be obtained by the following method:

A METHOD FOR THE PREPARATION OF PSEUDOCOCCIDAE FOR ROUTINE IDENTIFICATION

1. If the speciments are soft to begin with, puncture with needle on dorsum. Place speciments in a test-tube and add a 10% solution of KOH. Heat in a water bath for 5 minutes or even longer if heavily sclerotised.

2. Remove specimens to watch glass or glass dissecting block and express body contents by gentle pressure keeping insect pressed dorso-ventrally. In mealybugs hard wax crystals usually form inside the body and these may be dissolved by first dehydrating the specimens in alcohol and then placing them in Carbol Xylene for about 10 minutes. Place in alcohol again to remove Carbol Xylene. Carbol Xylene is composed of Xylene - 3 parts, Carbolic Acid crystals - 1 part.

3. Stain for about one hour in the following: Acid Fuchsin 0.5 gr., 10%. H.Cl 25cc., distilled water 300cc.

4. Transfer to absolute alcohol to completely dehydrate and then to Clove Oil or Terpineol and leave for about ½ hour.

5. Place specimens on microscope slide and remove surplus Clove Oil or Terpineol with fine filter paper. Put a drop of Canada Balsam on specimens and lower cover slip gently.

Characters separating mealybugs from other scale insect families are dorsal ostioles, antennae with 4-9 segments almost parallel for the entire length after the first segment and not tapering. Body with a series of 1-18 pairs of cerarii each composed of 2 or more enlarged setae and a few trilocular pores. Both surfaces usually have numerous trilocular pores which secrete the mealy or powdery wax. The ovisac is secreted from special tubular ducts, and downy wax is secreted from the multilocular pores to protect the eggs. A ventral circulus is situated between the fourth and fifth segments.

Mealybugs have reduced major characters that can be used for the recognition of species. General and species are therefore usually separated by the differences in distribution of pores and setae which are rich in variety. A composite illustration showing most of the morphological structures used in identification is shown in Fig. 1 reproduced from McKenzie (1967).

Species on Cassava may be identified from the following key:

KEY TO MICROSCOPIC CHARACTERS OF WORLD SPECIES OF MEALYBUGS ON CASSAVA

1. Anal lobe pair of cerarii present only. Dorsal tubular ducts large, each with orifice surrounded by a sclerotised area with 1-5 setae. (Zaire, Congo R., A.O.F., Togo, Sierra Leone, Ghana, Kenya, Somalia, Tanganyika, Zanzibar, Philippines, Mariana Is., Guam, Papua New Guinea, Malaya, Virgin Is.) ..... Ferrisia virgata (Ckll.)

-. With at least 5 pairs of cerarii. Large dorsal tubular ducts absent

2. Antennae 7-segmented. Cerarii on all abdominal segments with the cerarian setae widely separated. Enlarged setae, resembling cerarian setae, forming rows on midline and on submedian areas of dorsum. (Florida) ..... Nipaecoccus nipae (Mask.)

-. Antennae 8 or 9 segmented. Cerarii with cerarian setae close together. If enlarged setae are present on dorsum they do not form rows on midline or submedian areas

3. Dorsum with oral rim ducts

-. Dorsum without oral rim ducts

4. Antennae 9 segmented. Cerarii present on last 5 segments of abdomen only. Oral rim ducts abundant in bands across the segments, of one size. (Philippines) ..... Maconellicoccus hirsutus (Green)

-. Antennae 8 segmented. Cerarii numbering 17 pairs. Oral rim ducts not numerous, in groups of 2 or 3 near each cerarius, of 2 sizes. (Zaire, San Thome, A.O.F., Togo, Portugal) ..... Pseudococcus longispinus (Targ.)

5. Cerarii numbering 17 pairs. Auxiliary setae associated with each cerarius. Discoidal pores, each larger than a trilocular pore, conspicuous on posterior abdominal segments

-. Cerarii numbering 18 pairs. Auxiliary setae absent in each cerarius. Discoidal pores absent on posterior abdominal segments.

6. Dorsum of anal lobe segment with submedian setae considerably longer than other dorsal setae. (Zaire) ..... Dysmicoccus brevipes (Ckll.)

-. Dorsum of anal lobe segment with submedian setae short, about same size as other dorsal setae. (Guadeloupe) ..... Dysmicoccus bispinosus beardsley.

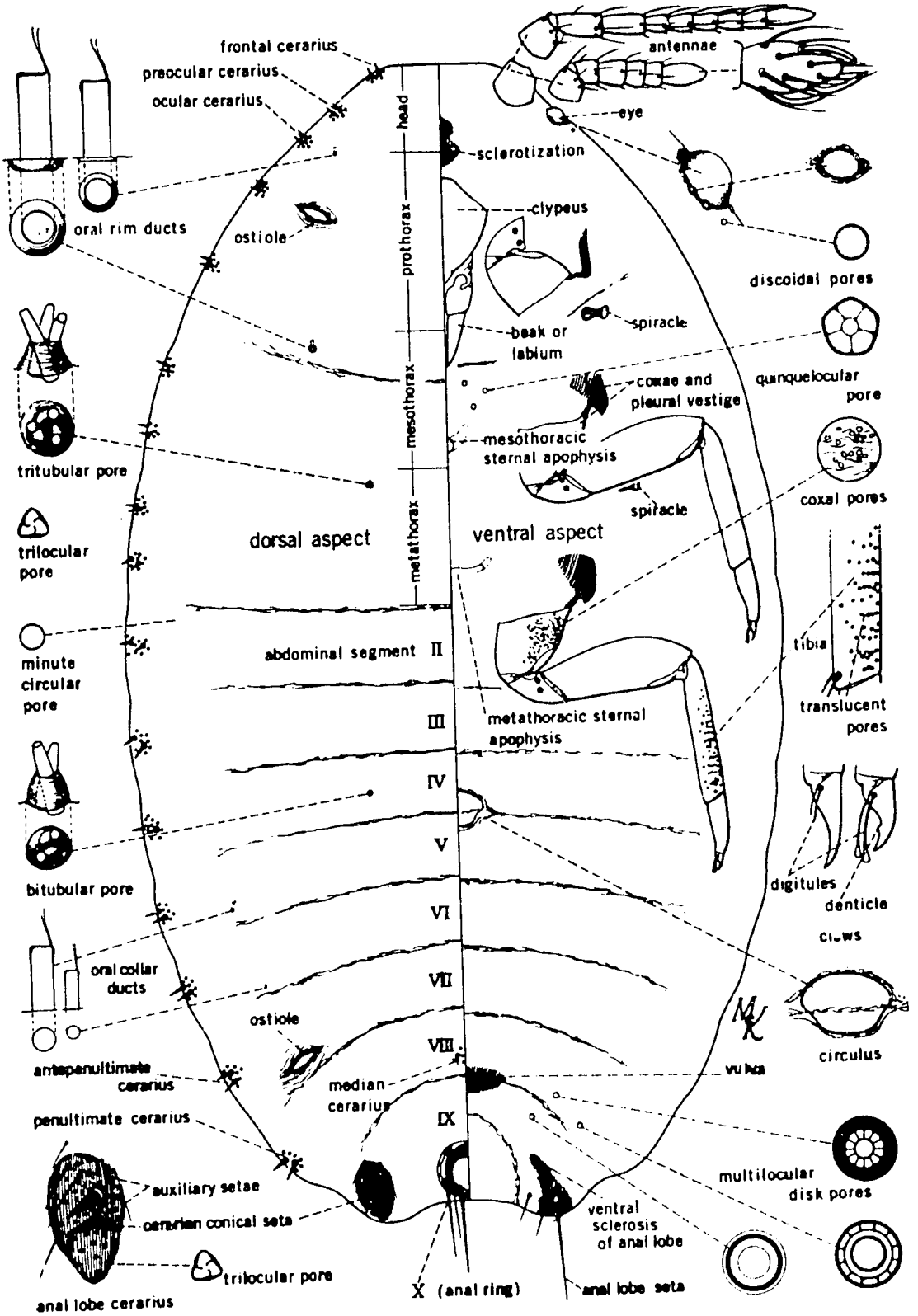

Fig. 1. Generalised drawing showing morphological structures of the mealybug family, Pseudococcidae.

7. Antennae 8 segmented. Anal lobe bar present. Claw without denticle. Quinquelocular pores absent. (Zaire, Congo R., A.O.F., Togo) ..... Planococcus citri (Risso)

-. Antennae 9 segmented. Anal lobe bar absent. Claw with denticle. Quinquelocular pores present.

8. Dorsal multilocular disc pores numerous in rows on abdomen

-. Dorsal multilocular disc pores, if present, numbering only a few around margins. (Zaire, Congo R., ? Gabon, ? Angola, Brazil) ..... Phenacoccus manihoti M.-F.

9. Head and thorax with distinct dorsal cerarii. (Nigeria) ..... Phenacoccus madeirensis Green

-. Head and thorax without distinct dorsal cerarii. (Brazil, Colombia) ..... Phenacoccus gossypii Towns. & Ckll. (Further research may prove that these two species are the same).

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Legend for Figure

Fig. 1. Generalised drawing showing morphological structures of the mealybug family, Pseudococcidae. "Copyright 1967 by The Regents of the University of California, reprinted by permission of the University of California Press."

A SYNOPTIC REVIEW OF THE BIOLOGY AND ECOLOGY OF SUGAR-CANE MEALYBUGS

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1. ABSTRACT

The biology and ecology of sugar-cane mealybugs are briefly reviewed. The species involved and their geographical distribution are given. The generalized life history is briefly described. An account of the feeding habit and damage is given and the factors regulating natural populations are outlined.

2. INTRODUCTION

The name 'mealybug' refers to members of the Homopterous family Pseudococcidae in the Coccoidea and is derived from the mealy or waxy secretions that generally cover the body. They have well-developed legs and the female body is distinctly segmented. Some species lay eggs, others ovoviviparous. They have a world-wide distribution and attack a wide range of plants.

Mealybugs have been reported on sugar-cane from the early days of its cultivation and the literature on them is fairly extensive. In this paper, only those important and generalized aspects of the biology and ecology are briefly reviewed, citation being confined to the more important contributions.

3. THE SPECIES AND THEIR GEOGRAPHICAL DISTRIBUTION

The mealybugs that have been recorded on sugar-cane are listed in Table I. The species that have sugar-cane as an important host plant include Saccharicoccus sacchari (Ckll.), Pseudococcus saccharifolii (Green), P. saccharicola Takah, Ripersia sacchari Green, and Trionymus radicicola (Morr.). These species also occur on other members of the Gramineae and occasionally on Cyperaceae. Dysmicoccus brevipes (Ckll.), an important past of pineapple, Planococcus citri (Risso), which is important on citrus, and Ferrisiana virgata (Ckll.), which occurs on a number of crops including cassava, coffee, cacao, cashew and groundnut, occur only rarely or sporadically on sugar-cane. Full information on the incidence and georgraphical distribution of sugar-cane mealybugs is given by Box (1953) and Dick (1969).

4. BIOLOGY

Life histories for the various species recorded on sugar-cane vary with environmental conditions in different countries and only generalised features of the biology are given in this article.

There is an almost complete range from bisexuality to parthenogenesis in the Pseudococcidae. From the evidence available, it seems bisexual reproduction is normal in Dysmicoccus boninsis (Kuw.) (Garrett, 1910) and P. saccharifolii (Ali, 1962). Parthenogenesis is normal in S. sacchari in which males are always rare (Uichanco and Villanueva, 1932; Guagliumi, 1962: Carnegie et. al., 1974). P. saccharicola is in an intermediate position with parthenogenesis being more common despite the occurrence of winged males (Rao, 1943a). The time between oviposition and hatching varies. Ali (1958) recorded 5-6 days for P. saccharifolii; Williams (1931) recorded 10 days for D. boninsis. On the other hand, in R. sacchari the period is reported to be only about 14 hours (Ali, 1958), while in S. sacchari the eggs hatch within an hour of being laid under the conditions prevailing in South Africa (Carnegie et. al., 1974). In the last two species, eggs are retained in the genital tract of the female until their development is well advanced. In the Philippine Islands, Uichanco and Villanueva (1932) found the period before eclosion in S. sacchari to be longest in the dry season and shortest in the wet season, the maximum period being 3 days. They observed that eggs were sometimes retained long enough to hatch within the body of the parent female and the young produced moulted within a few minutes of birth.

The recorded number instars varies among species but there is always at least one more instar in males than in females (Dick, 1969). Males usually have two functional wings, the hind pair being reduced to structures resembling the halteres of Diptera. Occasionally, wingless males are found even in species such as S. sacchari that normally produce winged males (Rao, 1943b).

The reproductive potential of mealybugs is high. In S. sacchari, for example, the female seldom takes more than a month to become sexually mature and may produce as many as 1000 eggs (Carnegie et. al., 1974). Detailed account of morphological features of females and males; together with life cycles are contained in various works. For example, Uichanco and Villanueva (1932) give detailed information on S. sacchari and Roa (1943a) gives similar information on P. saccharicola.

5. FEEDING BEHAVIOUR AND DAMAGE

Parts of Host Plant attacked

The mealybugs recorded on sugar-cane feed on various parts of the plant. P. saccharifolii feeds on the leaf lamina and the upper part of leaf-sheath (Issac and Misra, 1933); P. saccharicola attacks distal parts of the leaf (Rao, 1943a) or leaf bases (Pemberton, 1963).

S. sacchari and D. boninsis commonly occur on the stalk, usually underneath leaf-sheath cover, the youngest colonies being found on the youngest part of the stem (Dick, 1969). They have also been found at bases of shoots, sometimes below soil level (Beardsley, 1960). Although S. sacchari is found mainly in the nodal region of the stem, it was recently reported occurring on roots (Carnegie et. al., 1974). On sugar-cane, D. brevipes attacks roots or stalks at or just below ground level (Dick, 1969). Antonina graminis (Mask.) occurs on the root band on stalks (Pemberton, 1938); Trionymus diminutus Leon, is recorded from stalks (Pemberton, 1963) and R. sacchari attacks nodes underneath leaf-sheaths or underground parts of stems and roots (Ali, 1962). T. radicicola feeds exclusively underground, especially on small lateral roots (Stahl, 1927) while T. pygmaeus De Lotto was recently collected by the writer (1970) from sugar-cane roots in Kenya.

Feeding site and Damage

Plant-sucking insects usually affect their hosts through mechanical damage caused by stylests in the course of penetration through tissues; by the dissolving action or toxic nature of saliva produced during feeding; and by injection of pathogens into tissues. The path of stylet penetration and mechanical damage caused by mealybugs on sugar-cane do not appear to have been studied before. However, in a recent study on S. sacchari by the writer (unpubl.) it was found that the stylet pierces through epidermal cells and penetration occurs intra-cellularly through parenchyma, the vascular tissue apparently being avoided. This feeding behaviour resembles that of the sugar-cane scale, Aulacaspis tegalensis (Zehnt.) (Williams, 1970; Oloo, 1973). From the material examined, no mechanical injury or toxic effect could be seen on the cells pierced by the stylet and tapped or on neighbouring tissues, as is the case with other plant-feeding bugs.

Mealybugs in general have sometimes been regarded as unimportant on sugar-cane. However, various effects on cane production have been reported, such as impaired germination and growth or death of plants (Stahl, 1927; Barreto, 1932; Uichanco and Villanueva, 1932; Rao, 1943a; Dick, 1953; Ali, 1962) and reduction in yield through loss of sucrose or death of plants (Garrett, 1910; Barber, 1923). Early workers investigated mealybugs as possible vectors of several virus diseases such mosaic disease, Fiji disease or dwarf disease and ratoon stunting disease, but with negative results (Dick, 1969), although some members of the Pseudococcidae are known to be disease transmitters. More recently in India, P. saccharifolii has been shown to be the vector of spike disease on sugar-cane, a condition suspected to be caused by a virus (Ali, 1962).

6. ECOLOGY

As the relationship between the mealybugs and the host plant has already been discussed, only dispersion and the major factors influencing field populations will be described in this section.

Dispersion

The younger stages of the mealybug move actively on the host plant but as they mature they become less active and adult females are almost entirely sedentary. Although the first instar nymphs are capable of considerable locomotion, they generally move only from older to younger parts of the same host plant or adjacent plants. Older nymphs usually move from their feeding sites mostly when disturbed or when conditions become unsuitable. Hence, other means of dispersion have been suggested for spread from field to field or for infestation of new areas.

Williams (1931) suggested dispersion of nymphs by wind and those of S. sacchari and D. boninsis have been caught about 50 metres downwind from the nearest sugar-cane (Beardsley, 1960). Several species of ants are associated with mealybug colonies (Table 2) from which they obtain honeydew and they have been reported responsible for dispersion of younger stages. In the Philippines, three ant species carried young nymphs of S. sacchari to fresh feeding places (Uichanco and Villanueva, 1932); in Cuba, Stahl (1927) noted Tapinoma melanocephalum to be largely responsible for the spread of T. radicicola on cane roots; and in South Africa, Pheidole megacephala, Myrmicaria natalensis and Solenopsis punctaticeps associated with S. sacchari are believed to assist its dispersion (Carnegie et. al., 1974). However, (Dick, 1969) states that planting of infested setts, especially if leaf-sheaths are not removed, and the transport of infested canes are probably the most important means of spreading sugar-cane mealybugs.

Population-regulating Factors (Natural Enemies)

Although climatic factors are known to affect mealybug numbers considerably, natural enemies, whether indigenous or introduced, are perhaps the most important factor in checking field populations. All the parasites so far recorded from sugar-cane mealybugs belong to the Hymenopterous family Encyrtidae. The parasite species and their respective hosts are given in Table 3. Some parasites are specific in their host relationship, such as Aphycus terryi Full on D. boninsis in Hawaii and Anagyrus saccharicola on S. sacchari (Dick, 1969). Both parasites are effective in controlling their respective hosts and have the advantage of being able to thrive at fairly low host densities (Beardsley, 1960).

The predators of sugar-cane mealybugs are listed in Table 4. Probably the most important are members of the Coccinellidae, which generally feed on a wide range of insects. Among the more common predators include Cryptolaemus montrouzieri Muls., a native of Australia which has been introduced in many countries for mealybug control. Hyperaspis trilineata Muls. is reported to give adequate control of S. sacchari in Venezuela where it is indigenous (Box, 1950). Predacious larvae of a number of Diptera are frequently found among sugar-cane mealybugs, the most important being the Drosophilid Citona perspicax Knab. which is considered effective in Hawaii (Beardsley, 1960). It is noted that ants associated with mealybugs usually reduce effectiveness of parasites and predators (Dick, 1969).

The pathogenic fungi recorded from sugar-cane mealybugs are given in Table 5. Among these, Aspergillus, seems to be the most important, but its effectiveness is markedly influenced by climatic conditions. In the Philippines, A. parasiticus Speare controls S. sacchari during wet weather only (Dick, 1969). In Hawaii, mealybugs especially S. sacchari are commonly infected with Aspergillus during wet weather when heavy mealybug populations may be almost completely destroyed, and it is suggested that seasonal fluctuations of mealybug populations may result from this factor (Beardsley, 1960).

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TABLE 1. SUGAR-CANE MEALYBUGS - SPECIES AND GEOGRAPHICAL DISTRIBUTION.

Species	Country
Antonina graminis (Mask.) (indica Green)	India, Philippines, Hawaii (immigrant)
Dysmicoccus boninsis (Kuw.) (calceolariae Mask., aegyptiacus Hall.) (Dactylopius, Pseudococcus, Trechocorys, Trionymus)	Practically all sugar cane countries
Dysmicoccus brevipes (Ckll.) (bromeliae Bouche pseudobrevipes Mamet) (Pseudococcus)	Egypt, Caroline Islands, Guam, Queensland, Fiji, Puerto Rico, Hawaii (immigrant, Brazil), Mauritius
Eumyrmococcus smithi Silv.	Formosa
Ferrisiana virgata (Ckll.) (Pseudococcus)	Zanzibar
Mizococcus sacchari Takah	Formosa
Neorhizoecus sp. nr colobiensis Hamb.	Barbados
Planococcus citri (Risso) (Pseudococcus)	Egypt (?), Mauritius, Brazil, Guyana
Pseudococcus saccharicola Takah	India (probably an accidental introduction), Formosa
Pseudococcus saccharifolii (Green)	India, U.S.A.
Pseudococcus trispinosus Hall	Egypt
Pseudococcus variabilis Hall	Egypt
Ripersia cellulosa Hall	Egypt
Ripersia internodii Hall	Egypt
Ripersia sacchari Green	India, Burma
Ripersia sp.	Queensland
Ripersia sp. or spp.	West Indies
Saccharicoccus sacchari (Ckll.) (Dactylopius, Pseudococcus, Trechocorys, Trionymus)	Practically all sugar cane countries
Trionymus diminutus Leon.	Formosa
*Trionymus pygmaeus De Lotto	Kenya
Trionymus radicicola (Morr.) (Ripersia)	Cuba
Trionymus rostellum Lobdell	Hawaii

(Source of information: (1) Dick, J. 1969; (2)* Oloo, G.W. (1970).

TABLE 2.

Ant	Mealybug	Country
Acropyga marshalli Crawf.	Neorhizoecus sp. nr colombiensis Hamb.	Barbados
Camponotus abdominalis floridanus Buckley	Dysmicoccus boninsis	U.S.A. (Ga)
Camposotus barbatus taylori Forel	Saccharicoccus sacchari	Philippines
Camponotus compressus F.	Pseudococcus saccharicola	India
Dorymyrmex pyrameius Roter	Dysmicoccus boninsis	U.S.A. (Ga)
D. pyrameius niger Perg.	Dysmicoccus boninsis	U.S.A. (Ga)
Iridomyrmex humilis Mayr	Dysmicoccus boninsis	U.S.A. (Ga)
	Saccharicoccus sacchari	Hawaii
Irodomyrmex sp.	and other mealybugs	Hawaii
Monomorium floricola philippinensis Forel	Saccharicoccus sacchari	Papua, New Guinea
Odontomachus haematoda insularis Wheeler	Saccharicoccus sacchari	Philippines
Paratrechina longicornis Latr.	Trionymus radicicola	Cuba
Paratrechina (Nylandria) sp.	Saccharicoccus sacchari	Philippines
Pheidole megacephala F.	Saccharicoccus sacchari	Philippines
Polyrhacis dives Sm	Dysmicoccus boninsis	Hawaii
Prenolepis fulva Mayr.	Saccharicoccus sacchari	Natal
	Saccharicoccus sacchari	Philippines
	Dysmicoccus brevipes, D. boninsis	Brazil
		Puerto Rico
		Hawaii
	Pseudococcus saccharicola	Guyana
		India
		Cuba
		Puerto Rico
		Hawaii
Solenopsis geminata rufa Jerd.	Trionymus radicicola	Guyana
Solenopsis spp.	Saccharicoccus sacchari	Cuba
Tapinoma melanocephalum F.	Dysmicoccus boninsis	Philippines
	Saccharicoccus sacchari	Venezuela
Tetramorium guineense L.	Trionymus radicicola	Cuba
	Dysmicoccus boninsis	Philippines
		U.S.A. (Ga).

(Dick, J. 1969).

TABLE 3. PARASITES OF SUGAR-CANE MEALYBUGS.

Parasite	Host	Country
Anagyrus saccharicola Timb.	Saccharicoccus sacchari	India, Philippines Hawaii (intr.) Reunion Mauritius
	Ripersia sacchari	India
Anagyrus sp.	Saccharicoccus sacchari	Hawaii (intr.)
Anagyrus spp. (3)	Saccharicoccus sacchari	Philippines
*Anagyrus sp.	Saccharicoccus sacchari	East Africa
Aphycus terryi Full. (Pseudococcobius)	Dysmicoccus boninsis	Huan, Hawaii U.S.A. (intr.)
Blepyrus saccharicola Gah.	Dysmicoccus sp.	U.S.A.
	Dysmicoccus sp. probably boninsis	
Coccidencyrtus sp.	Saccharicoccus sacchari	Puerto Rico
Coccidoctonus trinidadensis Crwf.	Saccharicoccus sacchari	Puerto Rico
Coelaspidia osborni Timb.	Dysmicoccus boninsis	Mexico
Leptomastix dactylopii How. (Paraleptomastix)	Pseudococcus saccharifolii	India
Leptomastix sp.	Pseudococcus saccharifolii	India
Pseudaphycus mundus	Dysmicoccus boninsis	U.S.A.
	Saccharicoccus sacchari	Puerto Rico (introduced)
Xanthoencyrtus Fullawayi Timb.	Saccharicoccus sacchari	Hawaii
Xanthoencyrtus sacchari Mashood Alam	Ripersia sacchari	India
Xanthoencyrtus sp.	Pseudococcus saccharifolii	India

(Dick, J. 1969; *Ann. reports, 1969)

TABLE 4. PREDATORS OF SUGAR-CANE MEALYBUGS.

Predator	Mealybug	Country
COLEOPTERA		
Coccinellidae		
Brumus suturalis F.	Pseudococcus saccharicola	India
Cryptogonus orbiculus Gyll.	Saccharicoccus sacchari	Philippines
Cryptolaemus	Dysmicoccus boninsis	Queensland
		Mauritius (intr.)
		Guam (intr.)
	Dysomicoccus brevipes	Hawaii(intr.)
		Queensland,
	Saccharicoccus sacchari	Hawaii(intr.)
		Queensland,
		Hawaii(intr.)
		Somaliland (intr.)
		Mauritius (intr.)
Hyperaspis festiva Muls. (apicalis Wse).	Saccharicoccus sacchari	Guyana
Hyperaspis trilineata Muls.	Dysmicoccus boninsis	Hawaii(intr.)
		West Indies
	Ripersia sp.	Barbados?
	Saccharicoccus sacchari	Guyana
		Barbados,
		Venezuela,
		Guyana
Pharoscymnus horni Weise (as P. grimeti Muls.)	Saccharicoccus sacchari	Hawaii (intr.)
Scymnus andrewsi Sic.	Saccharicoccus sacchari	India
Scymnus (Pullus) apiciflavus Motsch.	Pseudococcus saccharifolii	India
	Saccharicoccus sacchari	Hawaii (intr.)
Scymnus bilucernarius Muls. (pictus Gorh.)	Dysmicoccus boninsis	Malaya
Scymnus coccivora Ram.	Saccharicoccus sacchari	Trinidad
Scymnus intrusus Horn.	Pseudococcus saccharifolii	Trinidad
	Dysmicoccus boninsis	India
	Saccharicoccus sacchari	U.S.A.
Scymnus mauritiusi Kors.	Dysmicoccus boninsis	Costa Rica (doubtful)
Scymnus nubilus Muls.	Pseudococcus saccharifolii	Mauritius
Scymnus (Pullus) sp.	Saccharicoccus sacchari	India
Scymnus sp.	Saccharicoccus sacchari	Phillippines (intr.)
Scymnus bilucernarius Muls.)	On sugar cane infested	India
Scymnus debilis Lec.))	with Dysmicoccus boninsis	Hawaii
Scymnus ocellatus Sharp)	and	
Scymnus roepkei Fluiter)	Saccharicoccus sacchari	

(Dick, J. 1969)

TABLE 4. (CONT'D).

Predator	Mealybug	Country
DIPTERA		
Drosophilidae		
Gitona perspicax Knab. (Gitonides)	Dysmicoccus boninsis	Hawaii
	Pseudococcus saccharifolii	Mauritius
	Saccharicoccus sacchari	India
		Hawaii
		India
		Mauritius
		Papua, New Guinea
		Philippines
Itonididae		
Karschomyia cocci Felt	Saccharicoccus sacchari	Puerto Rico
Schizobremia jujubae Barnes	Planococcus citri	Mauritius
Sciomyzidae		
Leucopis sp.	Saccharicoccus sacchari	Somalia
HETERROPTERA		
Anthocoridae		
Scoloposcelis parallelus Motsch.	Saccharicoccus sacchari	Java
Cardistethus pseudococci Wagner	Saccharicoccus sacchari	Egypt
Lygaeidae		
Macropes humboldti Dist.	Saccharicoccus sacchari	Papua, New Guinea
NEUROPTERA		
Chrysopidae		
Chrysopa claveri Nav.	Saccharicoccus sacchari	Guyana
Chrysopa silvana Nav.	Saccharicoccus sacchari	Venezuela
DERMAPTERA		
Proreus simulans Stal	Saccharicoccus sacchari	Philippines
Chelisoches morio F.	Saccharicoccus sacchari	Philippines

(DICK, J. 1969).

TABLE 5. FUNGI THAT CAUSE DISEASES OF SUGAR CANE MEALYBUGS.

Fungus	Host	Country
Acremonium griseum Petch	Planococcus citri Risso	Mauritius
Aspergillus flavus Lk.	Dysmicoccus boninsis	Puerto Rico
	Saccharicoccus sacchari	Puerto Rico
		Egypt
Aspergillus sp. (probably flavus)	Saccharicoccus sacchari	Venezuela
Aspergillus parasiticus (speare	Dysmicoccus boninsis	Hawaii
		Mauritius
	Saccharicoccus sacchari	Hawaii
Aspergillus sp.	Dysmicoccus boninsis	Philippines
	Saccharicoccus sacchari	Cuba
		Cuba
Entomophthora pseudococci Speare	Saccharicoccus sacchari	Hawaii
Metarrhizium anisopliae (Metch.)	Saccharicoccus sacchari	Venezuela
	Planococcus citri Risso	Mauritius
Metarrhizium sp.	Dysmicoccus baninsis	Mexico

(DICK, J. 1969)

SOME THOUGHTS ON MEALYBUGS AND MEALYBUG MANAGEMENT

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The mealybug-Family Pseudoccidae-comprise one of the most numerous and widely distributed groups of homopterous plant parasites. Among the Coccoidea, mealybugs are second only to the armored scale insects (Diaspididae) in numbers of known species. Eventually mealybugs may be found to actually outnumber the diaspidids, as the latter have been more thoroughly studied in most areas.

No recent world catalogue of the Pseudococcidae exists, although such a catalogue is badly needed. The exact number of described mealybug species has not been tabulated in published form since the last supplement to the Fernald Catalogue was published, 65 years ago, but it is believed now to be about between 2 and 3 thousand. About 160 genera are presently recognized. The mealybug faunas of Europe and North America have been fairly well studied, although undescribed species still turn up in these areas. In most other parts of the world and particularly in the tropics where the greatest proliferation of species has occurred, mealybug faunas are still very poorly known. It is estimated that at least half of the existing mealybug species of the world remain to be described.

In terms of their geographical distribution, mealybugs are the most widespread of all the Coccoidea. Indigenous representatives occur on all major land masses of the world (except Antarctica) and on most oceanic islands as well. They occur from the equatorial tropics to subarctic and the subantarctic regions, almost to the limits of distribution of vascular plants. Despite the wingless state of the neotenic females, mealybugs have been able to reach even the most remote oceanic islands. In some of the more isolated island groups, the Hawaiian chain and the subantarctic islands for example, mealybugs constitute almost the entire endemic coccid fauna. As with other groups of Coccoidea, man's habit of moving living plants from one geographic area to another has resulted in the wide distribution of many mealybug species, and in the repeated occurrence of mealybug pest outbreaks.

Mealybug taxonomy has been built almost entirely on the comparative external morphology of the neotenic adult female stages. The adaptive characters which are most often used in mealybug classification, principally minute cuticular such as gland orifices and setae of various types, frequently exhibit a marked degree of intraspecific variation. This has contributed to extensive synonomy, often involving widespread and economically important species. In addition, supraspecific relationships frequently have been obscured by convergent evolution. Most often this takes the form of reduction or loss of the same structures in groups which may not be closely related. Biological evidence has enabled us to recognize pairs or groups of sibling species which were formerly considered to be single species. Many more such complexes probably exist. The widespread striped mealybug, Ferrisia virgata (Cockerell), is an excellent example.

This "species" exists in both bisexual and parthenogenetic populations which appear to be not only reproductively isolated, but are also both karyotypically and morphologically distinguishable. In some areas, such as Hawaii, these two sibling species exist sympatrically. In other places only one or the other is presently known to occur. The species complexes of this sort which are presently known generally involve mealybugs of economic importance. The recognition and clarification of such complexes can be of major economic significance, particularly where biological control is being attempted. The case of the Kenya coffee mealybug, Planococcus kenyae (LePelley) is a classic example. Biological control of this important pest probably was delayed several years, and its cost materially increased, because identity of the species was confused with very closely related forms, particularly P. lilacinus (Cockerell). The natural enemies of P. lilacinus which were obtained in southeast Asia and the Philippines all failed against P. Kenyae. Biological control was not achieved until after LePelley showed that P. Kenyae was biologically distinct, and its native home was determined to be relatively nearby in central Africa.

The parasitoid wasps which are most frequently utilized in biological control programs against mealybug pests are often highly host specific. One case in Hawaii is known in which a parasitic encyrtid wasp proved to be better able to distinguish between species than entomologists who professed to be specialists in mealybug taxonomy. This involved a species complex which is still lumped under the name Nipaecoccus nipae (Maskell). In Hawaii, this mealybug exists in two color phases. These are actually biologically distinct species which, on the basis of the morphology of the slide-mounted adult females, appear to be indistinguishable. One form, which has predominantly white wax, faintly tinged with yellow, became a major pest of avocado and certain other plants in Hawaii before 1920. The second form, which produces buff-colored was and is generally found in the cooler upland and heavy rainfall areas of Hawaii, was a less serious pest. An encyrtid parasite, Pseudaphycus utilis Timberlake, was successfully introduced from Mexico during 1922, and almost immediately effected complete biological control of the whote-wax species. However, this parasite has never been reared from, and apparently does not attack, the buff wax species. More recently, structural differences were found in the adult males of these two mealybugs which appear to provide a morphological basis for their separation. A re-examination of Maskell's type material indicates that he had the species with buff-colored wax, and the white wax form therefore requires a new name. Material from South America which has been examined by the author suggests that there may be other sibling species within this complex. The unrecognized existence of such species complexes among mealybugs of economic importance may be one reason why introductions of promising species of mealybug parasites have sometimes failed.

A further example of this sort of taxonomic complexity is found in the pineapple mealybug group which at one time were under the name Dysmicoccus brevipes (Cockerell). It would be shown that the so called gray and pink "strains" of this mealybug, which are present in Hawaii, were morphologically as well as biologically distinct. The entity now called D. brevipes includes both a widespread parthenogenetic form and a somewhat less widespread bisexual form. The bisexual form causes green spotting of pineapple (as does D. neobrevipes which is also bisexual) whereas the parthenogenetic form does not.

Mealybugs, like all known Coccoidea, are characterized by female neoteny. The adult female stage is, in fact, a precocious larva in which the true imaginal form has been completely suppressed. The only true imago, in mealybugs (and in all other Coccoidea) is the adult male. Adult males are usually winged, although in some species the males have reduced non-functional wings. In the pink sugarcane mealybug, Saccharicoccus sacchari (Cockerell), both fully winged and apterous, larviform males are produced.

Because of the ephemeral nature of the adult males, they are seldom seen or collected by most entomologists, and as yet relatively few attempts have been made to utilize males in mealybug classification. However, male mealybugs do appear to possess useful taxonomic characters, not only for distinguishing between species (the male genitalia, for example) but also for indicating relationships between higher categories. Although, as was previously mentioned, several apparently obligate parthenogenetic species or "races" of mealybugs are known, the great majority are bisexual, and, with a little patience, adult males usually can be readily obtained. It is suggested that careful comparative studies of the adult males, as well as the immature stages of both sexes, will lead eventually to a more adequate system of mealybug classification both at the species level and with the supraspecific taxa.

A number of years ago it was attempted to evaluate sugar losses in Hawaii caused by light to moderate infestations of sugarcane mealybugs, principally Saccharicoccus sacchari, which then were, and still are, under reasonably good biological control. The study was not very successful as the differences between yields of mealybug-free and mealybug-infested plants were not statistically significant. However, the study did produce some useful information on mealybug biology and the relationships between these pests and the sugarcane plant. For one thing, very striking differences in the sizes of mealybug populations were encountered which developed in different cane varieties grown under identical conditions. Large populations appeared to be correlated not only with the physiological characteristics of the plants (i.e. with high sucrose content) but also with certain physical characteristics. For example, the largest populations developed on varieties with persistent leaf sheaths. On these, mealybug colonies were protected to a greater extent under the tightly adherent leaf sheaths than were colonies on self-stripping varieties. On the latter, exposure to the elements and accessibility to natural enemies resulted in rapid disappearance of the mealybugs once the leaf sheaths became loosened.

Another interesting fact emerged from our attempts to utilize systemic insecticides to maintain mealybug-free plants in these experiments. It was found that the gravid females of S. sacchari cease feeding and withdraw their mouthparts prior to the onset of oviposition. A single application of a systemic insecticide was not effective against this mealybug since the oviposition period extends for four weeks or more, and the non-feeding oviposition females continued to produce viable offspring well beyond the effective life of the insecticide in the plant. Thus, although S. sacchari produces eggs which hatch generally within a few minutes after oviposition, its response to systemic insecticides was similar to that of species which lay eggs that require several weeks before hatching.

Virtually all mealybugs produce honeydew, a material of high nutritive value which is utilized by a wide variety of insects, and is particularly sought after by ants. Ants, because of their habit of fostering mealybug colonies, and providing sanitation services and varying degrees of protection from natural enemies, frequently are a major factor in mealybug ecology. Indeed, certain mealybug species appear to have co-evolved with attendant ant species to the

extent that they can no longer survive in the absence of attending ants. Recent experimental studies on mealybugs and ants associated with pineapple in Hawaii have shown that the gray pineapple mealybug, Dysmicoccus neobrevipes Beardsley, which is the most important species involved in the pineapple wilt disease syndrome, does not survive on pineapple in the absence of attendant ants. When ants are excluded from pineapple plants infested with this mealybug, the mealybug colonies simply die out. Other mealybug species, for example the long-tailed mealybug, Pseudococcus longispinus (Targioni-Tozzetti), are able to survive on pineapple in the absence of ants, although these species generally are well controlled by natural enemies, and seldom develop economically significant populations. Ant interference with natural enemy activity appears to be the major cause of mealybug population build-ups and resultant wilt outbreaks, on pineapple in Hawaii. Therefore, the primary emphasis in mealybug wilt control in Hawaii has been on controlling the attendant ants. The species of greatest importance is the brown house ant, Pheidole megacephala (Fabricius), although the Argentine ant, Iridomyrmex humilis Mayr, and fire ant, Solenopsis geminata Fabricius, are important in some areas. Much of our present research effort is directed toward the development of ant bait formulations. It was suggested to develop an ant bait based upon an environmentally acceptable toxicant, rather than rely upon broadcast types of applications, for two principal reasons: (1) such baits have relatively little effect on non-target organisms, and (2) the toxicant is used at relatively low dosage rates.

The adverse effects of honeydew-gathering ants on mealybug natural enemies has been demonstrated on other crops, such as citrus in California, and is a factor which should be considered in any mealybug control program.

If one examines the case histories of the major mealybug pest outbreaks which have occurred throughout the world, two important facts are evident. Firstly, mealybug species have seldom been pests of major economic significance in areas where they are indigenous; and secondly, many outbreaks of introduced mealybug species have been successfully controlled by means of introduced natural enemies. In fact, it appears that mealybugs as a group have been as amenable, or more amenable, to successful biological control as has any other major group of insect pests. A recent world listing of biological control projects by Laing and Hamai (1976) includes 14 species of mealybug pests which have been partially, substantially or completely uncontrolled by means of purposely introduced natural enemies, the same number of species as the Diaspididae. Several other mealybug pests known to me have been controlled by accidentally introduced natural enemies; for example, the gray sugarcane mealybug, Dysmicoccus boninsis (Kuwana), the striped mealybug, Ferrisia virgata, and the Mexican mealybug, Phenacoccus gossypii (T. and C.) in Hawaii. Clearly, classical biological control still holds great promise for controlling introduced mealybug pests, particularly those species which are not vectors of plant diseases. Where attendant ants are a complicating factor, biological control of pest mealybugs may need to be combined with other control methods directed against the particular ant species involved.

If one lists the natural enemies which have been successfully utilized against mealybug pests one finds that, with the exception of the widespread coccinellid beetle Cryptolaemus montrouzieri Mulsant, and a few other coccinellids, the great majority of successful natural enemies of mealybugs have been internal parasitoid Hymenoptera, most of them belonging to the encyrtid tribe Anagyrini, a group which appears to be exclusively parasitic on mealybugs. Species of this group exhibit a relatively high degree of host specificity. Under natural conditions, their host ranges generally are restricted to a single species or to a few closely related species of mealybugs. It has been shown that a high degree of host specificity usually is correlated with well developed host seeking ability in

entomophagous insects. Thus, more often than not, it has been the more host specific types of natural enemies which have given successful biological control. With the exception of the entirely subterranean species, there appear to be few, if any, mealybug species which are not exploited by one or more species of anagyrine encyrtids, and I believe that it is among this large group of parasitoid wasps that most of the future successful natural enemies of mealybugs probably will be found.

BIOLOGICAL CONTROL OF MEALYBUGS (HOMOPTERA: PSEUDOCOCCIDAE) WITH SPECIAL REFERENCE TO CASSAVA MEALYBUG (PHENACOCCUS MANIHOTI, MAT-FERR.

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Biological control by introduced natural enemies (classical biological control) began with the control of a coccidoid - Icerya purchasi in California in 1888 - and the Coccidoidea comprise about 40% of the 225 attempts listed by DeBach (1964) where at least partial control was obtained. This list was updated in Huffaker & Messenger (1976) to include 327 more or less successful attempts, of which 25 have been achieved against mealybugs. The relatively large number of successes against Coccidoidea has been attributed to (a) the frequency with which they have been inadvertently introduced into new areas, (b) the difficulty of chemical control, and (c) various biological attributes (e.g. relative immobility, clumped distribution).

As a whole, biological control has been most frequently successful against introduced pests which, because only a few individuals have been involved in the introduction, have eluded their natural enemies. However it also requires the existence of a natural enemy which, if not host-specific, has a preference for feeding on the pest species and is capable of a rapid response to increases in pest numbers. In order to regulate the pest population and prevent periodic outbreaks, it must exhibit density dependence, destroy a greater proportion of hosts the greater their density, and be effective at low host densities. Coccidoidea are notable for the high incidence of host specific chalcidoid (Aphelinidae and Encyrtidae) parasitoids affecting them, and 15 of the 26 examples in Table 1 concern control by parasitoids alone, and 19, control by parasitoids and predators together. The predators used were all Coccinellidae, chiefly Cryptolaemus montrouzieri, Muls. which, although polyphagous, respond well to high host density, and frequently show preference for particular host species. The predators are especially effective in reducing high density populations and the parasitoids at finding hosts at low density. Thus, the ideal combination is an efficient coccinellid to reduce incipient outbreaks and a chalcidoid to maintain the host populations at a low density.

Attempts against 22 species have been traced in the literature. Many are poorly documented and there are doubtless others, especially in areas not covered by recent historical reviews. It will be seen that the successes have been achieved on islands and on continents; in temperate and tropical regions; on pasture grasses, sugarcane and tree crops. Failures are usually less well documented than the successes, but the reasons, where they can be determined, are instructive.

The control of the coffee mealybug (Planococcus kenyae) in Kenya illustrates several points. It appeared in 1922/23, probably introduced on passion fruit, and was first identified as Planococcus lilacinus, a south-east Asian species. During the 1930s, parasites of Pseudococcus calceolariae from California and Planococcus kraunhiae from Hawaii and Japan were tested, and either did not accept P. kenyae or failed to establish. Similarly, natural enemies of P. lilacinus sent from Indonesia were a failure. Only when its true identity and origin (Uganda) were appreciated was it rapidly brought under control by parasites introduced from Uganda in 1938. Since 1944 control has been complete except when ants, or use of persistent organochlorine insecticides, have disturbed the balance.

The lack of success in attempts to control the cocoa mealybug complex in Ghana is probably principally because the main pest, Planococcoides nialensis, is a native species and none of the introductions were adapted to it. The fact that it is a vector of a virus disease and therefore a pest at low density, also militated against control.

Ants are frequently listed as a cause of failure because they drive off natural enemies, or at least disturb them. Ants are believed to have played a part in the failure to control Pseudococcus obscurus in South Africa, and difficulties in obtaining control with the coccinellid Cryptolaunus montrouzieri in Spain, Italy and Indonesia (Celebes).

Another cause of failure is the inability of predators e.g. C. montrouzieri to reach hosts concealed beneath leaf sheaths, viz. Dysmicoccus brevipes on pineapple, D. boninsis and Saccharicoccus sacchari on sugarcane.

C. montrouzieri has been widely used against a number of species, particularly Planococcus citri. It has been successful where extreme climate (drought or cold) or seasonal shortage of hosts has not prevented establishment. In such places, control can be maintained by periodic releases where the expense is justified. In South Africa, establishment for the control of P. citri, only followed the establishment of Dactylopius spp. for the control of Opuntia spp. which overcame a seasonal shortage of P. citri. Control of the cactus was less successful than it might have been as a result. Similar interference with cactus control has occurred in Mauritius and Kenya. Consequently, C. montrouzieri should not be introduced where cactus control is important. No such danger is attached to the introduction of the more host specific parasitoids.

These failures and reservations apart, biological control of mealybugs has often been outstandingly successful and has most frequently been achieved by an efficient parasitoid. The successes are the more welcome because mealybugs (and other Coccidoidea) are not easily controlled with pesticides. The waxcovering repels contact poisons and the method of feeding necessitates the use of systemic stomach insecticides which are more expensive, more likely to contaminate produce and more toxic to man than commonly used contact chemicals.

The economic gains from this self-perpetuating method of pest control can be enormous; for example, following control of the Kenya mealybug it was calculated that for an outlay not exceeding £30,000, some £10 million had been saved up to 1959. DeBach (1964) estimated that the State of California had spent about $1.3 million on all biological control with a saving of about $18.7 million on five successful projects alone (including Pseudococcus calceolariae $2 million since 1930). Biological control has the advantage over most other methods in that (a) once achieved, it is permanent; (b) it is specific; (d) it is maintained without any need for recurrent input by the farmer. Thus, this method is ideally suited to peasant agriculture and a subsistence food crop where chemical methods are too costly, difficult to enforce and often dangerous when put in the hands of untrained personnel. The principal disadvantages are that success cannot be guaranteed in advance and may take time to achieve, so that finance for the necessary basic research is often difficult to find when funds are short or quick results are demanded.

Phenacoccus manihoti was only named following its invasion of Africa, an indication of its unimportance in its native South America. It is an obvious candidate for biological control for this reason and because it affects a subsistence crop. The fact that it is an indirect pest (not directly damaging the useful produce) and the relatively long growth period of the crop are also points in favour of attempting biological control. The International Development Research Centre (IDRC) of Canada has recognized the advantages of biological control and is funding a three-year project in which the CIBC will undertake exploration and research in South America and provide material for release and assessment in Africa.

The programme will be conducted on established lines. Now that the identity and origin of the pest is known, surveys will be made in climatically and ecologically similar areas within its natural distribution where it is not a pest. Natural enemies of P. manihoti and allied species will be assessed for their impact on host populations, host specificity and suitability for introduction. Promising species will be studied to obtain information on life history and breeding methods. Those finally selected will be shipped after elimination of hyperparasites, either using field-collected material or laboratory stock. Field material has the advantage of genetic diversity which may be reduced in culture, but the disadvantage that it is not always possible to eliminate hyperparasites or to collect sufficient numbers. Before shipment clearance will be obtained from the quarantine authority of the receiving country. Releases can either be made direct from shipped material, if adequate, or from material bred up in the laboratory.

Pre- and post- release assessments are required to measure impact of successful introductions. It should be remembered that the introduction is the crucial experiment and should be made as soon as possible. Once established, a species can readily be distributed from the field colony. Rapid passage to the field, and distribution from the field, not only guards against genetic deterioration of stock and hastens control, but hastens adaptation to the new environment. Back-up colonies should be maintained to guard against accidental extermination in the early stages of colonisation and to allow repeated releases if initial releases are not successful. Establishment may fail through release of inadequate numbers, inclement

weather, poor choice of site etc. as well as from inherent unsuitability for local conditions. Consequently, each species should be released over one or two complete seasons (unless prior establishment is attained) before being abandoned as a failure.

To date, Trinidad has been surveyed but no Phenacoccus spp. have been found on cassava. However, P. gossypii has been found on Lantana montevidensis and is attacked by a complex of three coccinellids - Hyperaspis onerata (Muls), Hyperaspis jucunda (Muls) and Nephus (Scymnobius) sp. near flavifrons (Melsheimer) - and a parasite - Aenasius phenacocci Bennett. Cultures of P. gossypii have been set up on potatoes and these species will be bred. If desired, an early start can be made in Africa by testing these species on P. manihoti and, if suitable, releasing them. The predators, at any rate, are not restricted to a single host and may prove useful. This course of action would at least serve to gain experience in handling mealybug natural enemies and may bring early relief.

TABLE 1

Summary of known biological control attempts against mealybugs

(F = failure. P = partial control. S = substantial control
C = complete control. ? = result unknown)

References are to recent reviews

Country	Natural Enemy	Origin date	Result
Antonina graminis (Mask.) - pasture grasses			
USA (Texas, Florida)	*Neodusmetia sangwani* (Rao) (Encyrtidae)	India 1959	S

Increase in yield following control of up to 44% reported. Result repeated in Bermuda (S - C) and also in Arizona, California, Mexico, Brazil, Israel. Introductions of *Anagyrus antoninae* (Timb.) are also being made into Florida, Mexico, Israel, but results not yet clear.

(Huffaker & Messenger 1976)

Dysmicoccus boninsis (Kuw.) - sugarcane			
Guam	*Cryptolaemus montrouzieri* Muls. (Coccinellidae)	Hawaii 1926	F

It became established but seldom feeds on this species.
(Rao et al 1971)

Dysmicoccus brevipes (Ckll)			
South Africa	*Cryptolaemus montrouzieri*	USA (Calif.) 1900, 1924	F

The predator was unable to reach D. brevipes, but was successfully established against *Planococcus citri*. In Mauritius (1938-9) it also failed, although it became established on the island.

(Greathead 1971)

Puerto Rico	*Hambeltonia pseudococcina* Comp. *Anagyrus ananatis* Gahan (Encyrtidae)	Brazil 1936-37	? P

Some success is claimed but the same parasites failed to establish in Hawaii. Similarly, no success was achieved in Florida although it became established.

(Clausen 1956; Huffaker & Messenger 1976)

Country	Natural Enemy	Origin date	Result
Ferrisia virgata (Ckll)	- coffee, fruit trees, ornamentals		
Java	*Cryptolaemus montrouzieri*	Hawaii 1918	?
It became established on coffee which is no longer an important crop. (Rao et al 1971)			
USA (California)	*Acerophagus texanus* (How.) (Encyrtidae)	Mexico 1965-67	?
Release along with other species. Established although one of the least promising species initially. (DeBach & Warner 1969)			
Nipaecoccus nipae (Mask.)	- subtropical fruits		
Hawaii	*Pseudaphycus utilis* Timb. (Encyrtidae)	Mexico 1922	S
(Pemberton 1964)			
Nipaecoccus vastator (Mask.)	- shade trees, citrus		
Egypt	*Anagyrus aegyptiacus* Moursi *Leptomastix phenacocci* Comp.	Java 1934-9	P
Other natural enemies introduced at the same time did not become established. (Kamal 1951)			
Saudi Arabia	*Cryptolaemus montrouzieri*	Pakistan 1972-3	?
C. montrouzieri became established but the final result is not known. (Simmonds 1974)			
Phenacoccus aceris (Sign.)	- apple		
Canada (BC)	*Allotropa utilis* Mues. (Platygasteridae)	Canada (Nova Scotia) 1938	C
The pest originated in Europe; A. utilis (origin unknown) was effective in Nova Scotia and so used. (McLeod et al 1963)			

Country	Natural Enemy	Origin date	Result
Maconellicoccus hirsutus (Green)			
Egypt	*Leptomastix phenacocci* *Anagyrus aegyptiacus* *Achrysopophagus sp.*	Java 1934-9	S

Other natural enemies introduced at the same time did not become established. (Kamal 1951)

Hyperaspis maindroni Sic. (Coccinellidae) was sent to New Guinea from India in 1971. Result not known. (CIBC reports)

Planococcoides njalensis (Laing) and others - cocoa			
Ghana	Many natural enemies of other species	Several countries. 1948-55	F

None are known to be established. Only *Pseudaphycus angelicus* (How.), a parasite of *Planococcus citri*, has been recovered. (Greathead 1971)

Planococcus citri (Risso) - citrus, grapes			
USA (California)	*Cryptolaemus montrouzieri*	Australia 1891-2	P
	Leptomastidea abnormis (Gir.) (Encyrtidae)	Sicily 1914.	

C. montrouzieri has been released in many countries. It achieved complete success in South Africa (1924) but this depended on the prior establishment of *Dactylopius spp.* against prickly pear cactus. *C. montrouzieri* interfered with control of the weed. Establishment and partial success was achieved in Chile (1931), Hawaii (1915), Corfu (1933), Italy (Liguria only) (1919-20), Portugal (1929), Egypt (1923). In some countries, success can be attained by annual releases, viz. Egypt, Sicily, Spain, France. It failed in Cyprus and Israel, where the summer climate was too harsh, and its use was abandoned in Egypt as the colonisation programme was too costly. In all areas, an essential for success is the continued presence of hosts throughout the year. *L. abnormis* also contributes to control in Chile, and *Leptomastix dactylopii* How. in Spain (1948). Both these parasites were introduced into the USSR in 1960 and are established.

(DeBach 1964; Greathead 1971; Kamal 1951-1976; Huffaker & Messenger 1976; Rivany 1968).

Country	Natural Enemy	Origin date	Result
Planococcus kenyae (Le Pelley) - coffee			
Kenya	Anagyrus sp. near kivvensis (Comp.) (Encyrtidae)	Uganda 1938	C

Initial failure using parasites of other mealybugs. Successful species (and four others established) from same host in area of origin. (Greathead 1971)

Planococcus lilacinus (Ckll)			
Sri Lanka	parasites (unspecified)	Philippines 195?	F

(Rao et al 1971)

Pseudococcus calceolariae (Mask.) - citrus and other fruits (gahani Green, fragilis Brian of authors)			
USA (California)	Coccophagus gurneyi Comp. Hungariella pretiosa (Timb.) (Encyrtidae)	Australia 1928	C

Success achieved after mass release of Cryptolaemus montrouzieri and establishment of another ladybird, Scymnus binaevatus (Muls.) from Australia had failed to give adequate control.

C. gurneyi has also been used in Chile (1936) and the USSR (1960) with success and is established in South Africa (1934), but its effect has not been assessed.

(Clausen 1956; Greathead 1971; Huffaker & Messenger 1976)

Pseudococcus citriculus Green - citrus			
Israel	Clausenia purpurea Ishii (Encyrtidae)	Japan	C

After solving problem of identity of pest parasites of the P. comstocki group were tested.

(Rivany 1968)

Pseudococcus comstocki (Huw.) - apple			
USA (eastern)	Allotropa burrelli Mues. (Platygasteridae). Pseudophycus malinus Gahan (Encyrtidae)	Japan 1939-41	C

Partial success was obtained with P. malinus in Uzbekistan in 1945 following its introduction from the USA.

(Clausen 1956; DeBach 1964).

Country	Natural Enemy	Origin date	Result
Pseudococcus longispinus (Targ.) (adonidum (L.) of authors) - citrus, avocado			
USA (California)	*Anarhopus sydneyensis* Timb.	Australia 1933	P
	Hungariella peregrina (Comp.) (Encyrtidae)		

Partial control with *H. peregrina* and *Anagyrus fusciventris* (Gir.), imported from California, was also achieved in Bermuda (1951). *Pseudophycus angelicus* (How.), introduced into South Africa (1934), failed but recent introductions of *A. sydneyensis* and *P. peregrina* to Israel show promise of success.

(Clausen 1946, Bennett & Hughes 1959; Greathead 1971; Huffaker & Messenger 1976)

Pseudococcus maritimus (Ehrh.) - pears, grapes.			
USA (California)	*Acerophagus notativentris* (Gir.)	? 1943	S

(Huffaker & Messenger 1976)

Pseudococcus obscurus Essig - grapes, pears			
South Africa	3 encyrtids and 2 *Scymnus* spp.	USA (Calif.) 1933-4	?

None are known to be established, but ant control has led to "natural" control of the pest.

(Greathead 1971)

Pseudococcus spp.			
Australia (Western)	*Cryptolaemus montrouzieri*	Australia NSW 1902	S

Substantial success has also been achieved in St. Helena (1973) *Coccophagus gurneyi* Comp. failed in the Cook Islands (1934). The result of recent introduction of *C. montrouzieri* is not known.

(Rao et al 1971; Simmonds 1974; Wilson 1960)

Country	Natural Enemy	Origin date	Result
Pulvinaria psidii Mask.	- shade trees		
Puerto Rico	*Cryptolaemus montrouzieri*	USA (Calif.) 1911	P
(DeBach 1964			
Bermuda	*Microterys kotinskyi* (Full.) (Encyrtidae) *Azya luticeps* (Muls.) *C. montrouzieri*	Hawaii 1953-7	C
(Coccidae. Bennett & Hughes 1959)			
Rastrococcus iceryoides (Green)	- coffee		
Celebes	*Cryptolaemus montrouzieri*	Java 1928	S
(Rao et al 1971)			
Saccharicoccus sacchari (Ckll)	- sugarcane		
Hawaii	*Anagyrus saccharicola* Timb. (Encyrtidae)	Philippines 1930	S

Success also achieved in Barbados (1970) and it is established in St. Kitts (1971), both from Uganda stock. Attempts to use *C. montrouzieri* in Somalia (1933), Philippines (1928), Egypt (1923), were abandoned as the predator is unable to penetrate beneath the leaf sheaths. *Hyperaspis trilineata* Muls. from Barbados has failed in India (1970) and both coccinellids have been released and recovered in the Bahamas (1969).

(Greathead 1971; Kamal 1951; Pemberton 1964; Rao et al 1971; CIBC reports).

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SUMMARY OF DISCUSSIONS[1]

Origin and Distribution

The mealybug has been reported in Northern Angola, Gabon, Congo Brazzaville, Zaire and Brazil. Quarantine efforts should be increased to restrict movement of planting material.

The cassava mealybug is of the American type. It could not have been introduced into Africa by wind forces. The most probable means was by the transfer of vegitative manioc materials into Africa.

Phenacoccus gossypii has been reported in Brazil and Colombia but not in Africa. However taxonomists still require the full range of mealybug specimens from Africa.

Development

It is still not understood what triggers the development of dormant mealybugs within leaf buds during short dry spells in the rainy season. The infested growing point with its bunched-top appearance serves as a protective umbrella and such populations endure during this period, serving as inoculum during the dry season.

Damage

There may be similarities between feeding of the sugar cane mealybug and the cassava mealybug. However it is suspected that the appearance of short internodes, cell enlargement and distortion in cassava may be due to the introduction of a toxin or growth inhibitor. No mechanical or chemical injury to cells has been observed in sugar cane. Histological studies in cassava may throw some light on the feeding activity of P. manihoti.

Dr. Dick's work in South Africa using infested cuttings of sugar cane was repeated in Hawaii. No differences in yield were observed between mealybug-free plants and infested plants. But there were varietal differences depending on the nature of leafsheets.

Cultural Control

The farming pattern in Bas-Zaire encourages soil erosion and degeneration. The practice of making ridges along slopes (5% or more), dry season bush fire, subsequent loss of organic matter and loss of top soil through erosion must be given some consideration. One only needs to look at the mountain slopes between Kinshasa and Matadi to

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1) The assistance of Dr. H.C. Ezumah in recording the discussions is gratefully acknowledged.

appreciate the negligent use of the land. The pest and disease problems notwithstanding, some good crop of manioc has been obtained at CEDECO, Kimpese where the following practices are observed:

- lay down the grass (or other vegetation) twice during the dry season and turn under before first rains
- plant early in October or November to tap mineralized nitrogen and other mobile nutrients in the soil before they are washed off by heavy rains
- mulch to conserve moisture and reduce weed competition
- grow cover crops at appropriate times
- farm on contours and not along slopes
- weed cassava fields within first six weeks of planting.

The use of fertilizers to enhance plant vigor must be handled with care. There are biochemical differences associated with moisture stress, plant metabolism and pest incidence. In sugar cane, protein hydrolysis and high amino acid concentration instead of protein synthesis are associated with stress. Excess iron increased amino acid content of sugar cane during the dry season and higher amino acid is positively related to higher mealybug populations.

Similarly, in cocoa, in a fertilizer trial, there were more Planococcus citri on seedlings grown in a nutrient solution with more available nitrogen.

Chemical Control

Treatment of manioc cuttings in a preliminary trial with an insecticide did not show any differences in yield compared to untreated plots. However a critical evaluation of this trial may indicate a delay in infestation of 1 - 2 months. The latter was the case at CEDECO, Kimpese using a mixture of 50 g. powdered soap, 10 l water, 300 ml diesel fuel and 50 g. malathion 25 E.C.

Hostplant Resistance

In searching for resistance we must assume that differences exist among genotypes. When a source of resistance is found it can be incorporated into high yielding clones. It is also necessary to note that not only highly resistant clones need be selected for but also clones with low - to--moderate levels of resistance. We may arrive at higher levels of resistance by combining two or more clones with low levels of resistance.

Biological Control

There has not been much success with the green cassava mite, Mononychellus tanajoa. The three predators (Oligota, Stethorus and Thyphlodromus) reported by Nyiira in Uganda were also found by CIBC in South America. Unfortunately they are only effective at high mite

populations. There is however hope of utilizing pubescent cassava varieties which have been found to be more tolerant to the pest.

Usually the first pest outbreak is very rapid and severe but in subsequent years it subsides and settles to an equilibrium level in the ecosystem. This level may be above the economic injury level and thus necessitate control measures.

Pest outbreak often occur as a result of the absence of natural controlling factors in the ecosystem. This may be caused by the introduction of the pest into new regions; use of chemicals may eliminate parasites and predators of an otherwise uneconomic pest, new agricultural technology etc. Biological control is not always as simple as it seems. Even when an effective natural enemy is found, it may not establish itself on the pest. For example the predator introduced into Hawaii for the control of the pineapple mealybug, Dysmicoccus neobrevipes Beardsley, would have been successful if the ants (especially Pheidole megacephala, Fabricius) associated with the mealybug had not been natural enemies of the predator.

Spalgis lemolea which has been reported in Zaire and Congo Brazzaville as a predator of P. manihoti may be already at its maximum controlling efficiency. The annual temperature fluctuation in Bas-Zaire is between 15 - 32°C. This is within tolerable limits for any introduced parasite or predator.

Now that the cassava mealybug has been correctly identified and its origin known, research on bio-control would follow established lines : search for natural enemies in its country of origin or climatically and ecologically similar regions where it is a pest; evaluation of natural enemies and introduction of promising species into the subject country.

RECOMMENDATIONS

Control strategies should place emphasis on breeding for hostplant resistance and biological control. However since these involve long term research, for short term results - both cultural and chemical approaches are encouraged and should be incorporated within the framework of an integrated pest management programme of the cassava mealybug.

Host Plant Resistance

The group recognizes the efforts in the screening of over 2000 cassava families. In the long run, hostplant resistance is the cheapest method of control and should be exploited. A wider spectrum of cassava germplasma in seed form from South America should be made. Many factors may contribute to resistance and the following characteristics should be taken into consideration :

(a) early maturing varieties If such varieties are planted early during the first season (October/November) they may escape heavy mealybug damage in the dry season.

(b) Pubescence : Pubescence varies with plant maturity and the degree of pubescence : density and angle of inclination have a role in determining its effectiveness.

(c) Plant vigour : To a large extent this is vital in plant susceptibility to attack more so since cassava is a dormant crop during the dry season when the pest is more serious.

(d) Canopy structure : Varieties may exist which can resist the bunchedtop symptom and thereby delay death of the growing point.

(e) Chemical antibiosis : Should cassava cultivars be found which possess toxic components to the mealybug, they should be exploited. In this regard more wild varieties should also be collected and screened. If resistant they should be incorporated into high yielding, desirable varieties.

Biological Control

Bio-control is the most promising line of approach. Since the Commonwealth Institute of Biological Control is already one step ahead in this project, cooperation between CIBC and IITA/PRONAM should be geared towards speeding up the process of release of natural enemies of the pest.

In view of the nature of the work involved with a new pest there is an urgent need for the identification of another entomologist to handle the phase of biological control. Such a position should be filled for no less than 2 years.

Recruitment and appointment of staff is usually a prolonged administrative procedure. In the absence of a specialist Entomologist in bio-control, a recent Ph.D may be recruited, trained briefly at CIBC or the Division of Biological Control at Riverside, California and seconded to PRONAM. Such an appointment should be augmented with visits by a consultant.

Funds for an Entomologist in Africa should be looked into and facilities at M'vuazi should be improved to handle this phase of control.

IITA/PRONAM entomologists should make contacts with other biological control laboratories and Entomologists working on this problem. It is necessary to pool efforts together and meaningful research in Africa should be centrally located rather than being scattered and isolated.

Natural enemies of the pest should be surveyed in West and Central Africa alongside with surveys in South America. There are possibilities for immediate preliminary release in Zaire of natural enemies of related species of P. manihoti. Should this be done, it must be understood that no success is guaranteed the Government of Zaire. In the event of a release constant monitoring, recapture and breeding will be necessary for an accurate assessment of success or failure.

Cultural Control

Farmers should be educated on the advantages of early planting of cassava. To obtain leaves for food all year round cultivars with different maturity dates should be advised.

Mulching for retention of soil moisture and soil conservation as practised in CEDECO, Kimpese should be encouraged.

Chemical Control

The entomologist should screen available insecticides for the treatment of cuttings. Hot water treatment, use of methyl bromide and mecuric chloride treatment of planting materials should also be examined.

A network of treatment centres should be proposed to the Department of Agriculture. Such a network will aid in restricting the spread of the mealybug to other regions in Zaire. The use of insecticides as foliar spray is discouraged since cassava leaves form a basic part of the diet. However insecticides may be screened of foliar application in the event of demands from the Government or Industrial production agencies for the treatment of large cassava plantations.

Quarantine

Movement of cuttings as planting material and leaves as vegetable within Zaire should be done with care. Introduction of planting material into Africa either from without or between African countries should be only in the form of seeds.

Standard regulations for movement of seeds given by the Inter-African Phytosanitary Council should be strictly obeyed.