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BIOLOGICAL CONTROL OF PESTS:

ITS POTENTIAL IN WEST AFRICA

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C.W. Castleton.

PREFACE

The USAID Regional Food Crop Protection Project's Annual Training Conference was expanded in 1981 to include participation of Agricultural researchers in a deliberate attempt to increase the interchange of ideas between research scientists and decision-makers within Ministries of Agriculture, or Rural Development regarding nonchemical means of pest management. Sixty four participants from ten countries attended, including the Directors of Crop Protection Services from most Sahelian countries.

The text is unfortunately limited to the formal scientific presentations. Conference activities such as the Exhibit hall, panel discussions on cost/benefit analysis, and probing question and answer sessions aren't readily captured in print. Hopefully, publication of the text will help to rekindle the discussion necessary to better utilize research results in the formulation of pest management policy, and to ensure that research is conducted to answer the questions faced by decision-makers.

In the delay between Conference and publication, I've noticed an increased effort in biocontrol field trials in several Sahelian countries. Nothing would please me more than to have the present text become outdated due to a marked increase in biological control research and its adaptation into practical control strategies for the key psts of Sahelian food crops.

C.W. Castleton
Conference Coordinator

AN OUTLINE OF BIOLOGICAL METHODS TO CONTROL CROP AND FARM PRODUCE PESTS

by Dr. G. Pierrard, F.A.O.*

Biological control. What exactly does this term mean? In the broadest sense, it includes all methods which reduce pest damage without the use of chemical pesticides, or which directly reduce pest populations. Within this context, biological control encompasses resistant crop varieties, pest habitat modification, and the use of pheromones and growth inhibitors. In the strictest sense of the word, biological control involves the use of natural enemies and the technique of sterile male release. This discussion will revolve around this restricted sense of the word.

The concept of biological control is not new. The first report on the use of natural enemies was written two centuries ago, dealing with the practices of date palm farmers in Arabia who introduced predatory ants to control termites. As scientists we must recognize the value of such writings, for this practice surely dates back to ancient times. Entomologists' interest in biocontrol is itself not new either. In 1884, at the University of Odessa in Russia, a special laboratory was created to produce spores of the fungus Metarrhizium anisopliae to control Anisoplia austriana in cereal crops. In California in 1889, a remarkably successful project was carried out in controlling the plum scale Icerya purchasi through the introduction of the coccinella Rodolia cardinalis. This scale did not become a problem again until after DDT was used to treat plums. In Thuringe, Germany circa 1911, the first trials were conducted to control a produce pest, Ephestia kuehniella, using Bacillus thuringeinsis. Finally, at the turn of the century, the Department

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* CILSS Project "Integrated Pest Management Research and Development against Principal Crop Pests in Sahelian Countries"

of Entomology at Massachussetts State College offered a course entitled "Insect enemies".

Research in the use of natural enemies developed rapidly between the two World Wars, but this method of control was eventually overshadowed by synthetic pesticides. Once again, man became the sorcerer's apprentice using on a large scale a procedure that he had not yet mastered.

Noone has mentioned the influence of the pesticide industry in explaining the widespread use of synthetic pesticides. However, it must be noted that this industry played its role to the fullest, while scientists did not sufficiently play theirs. They have, in fact, only belatedly worried about the harmful effects of intensive use.

To illustrate these harmful aspects, I will cite an American recipe given by P. de Bach, an eminent specialist in biological control: "Take 2 kg. of DDT 50% wettable powder and mix it with 400 liters of water. Using a 10 liter hand sprayer, apply 1-2 liters on each plum tree. Repeat the operation each month until the tree is defoliated or dies from the effects of attacks by the scale Aonidiella aurantii. Only 6-12 applications are necessary".

The rapid multiplication of this scale is due to the destruction of its natural enemies. A lesson can be learned from this example, other than that of knowing conditions prior to using chemical pesticides: these pesticides can benefit biological control studies by allowing artificially large pest populations to develop. These populations can in turn be useful in testing the effects of biological agents. Another negative effect of chemical pesticides (which doesn't in the least take away from the positive effects they've had) is the development of pesticide resistant pest species. In 1965, in the area of pest control, there were 182 recorded cases of pesticide resistance. In 1978 there were 392, even though the number of available pesticides had been increased. It is because of the resistance of the defoliating caterpillar <u>Protoparce sexta</u> that cotton farming has been abandoned in certain areas of the southwestern United States. Insecticides can no longer control this lepidoptera.

The failure of chemical control has stimulated research and development of other means to control pests. However, these have proven more difficult than the use of phytopharmaceutical products. The complexity of mastering these alternative means has stimulated extensive biological and ecological research. In certain cases, control efforts using these new methods have been remarkably successful. In other cases, chemical control programs have been revised. As a result of this research, the once passive idea of integrated pest management (applied by many entomologists before the concept was defined) has become an active theme, one of the most important components being biological control. The main advantages of biological control are: commonly of a specific nature; presenting no danger to the user, the consumer, or the environment; and having long term or even permanent effects.

Biological control uses both entomophagous insects and entomopathogens. The latter group includes bacteria, fungi, viruses, protozoa, and nematodes. With the exception of bacteria, however, progress in the development of application techniques is on the whole less advanced than that using entomophagous insects. It must be noted that biological control was first developed to control insects. However, a concerted effort should be made to use this control method against weeds, for herbicides comprise 45% of today's pesticide market. Entomophagous insects include parasites and predators. Parasites develop numerically, living on a single host, whereas predators feed on several prey. Most crop pests are attacked by many species of parasites and predators. Thus the question is raised of what natural enemies should be used in carrying out biological control research. The time of research that is haphazard or resulting from chance observation must come to an end. It is advisable, then, to conduct a serious preliminary study of the possibilities of using natural enemies. This would entail the following:

1) A better understanding of the bioecology of pests to be controlled in order to know, among other things, during what times pest populations are most vulnerable (these not necessarily being when population levels are low).

2) An understanding of the economics of pest damage in relation to acceptable pest population thresholds.

3) An understanding of the population dynamics of all pests on crops being studied and existing or short term solutions which should be sought in order to bring damages within acceptable economic thresholds. If pesticide use cannot be discontinued, perhaps it is preferable to choose entomopathogenes which are minimally or not at all affected by insecticides (if control of insect pests is desired).

If an analysis of these preliminary data shows that biological control has a chance to succeed, then research should be carried out in the following areas:

1) The bioecology of potentially effective entomophagous insects and entomopathogens. One should take into account biological control agents which are already or soon to be on the market, such as Bacillus thuringiensis, viruses, fungi, protozoa, and nematodes.

2) The possibilities of introducing or adapting biological agents from other areas. This course of action (as with the first) requires a precise identification of natural enemies. It is of note to recall that in California taxonomical confusion set biological control of Aonidielle aurantii back fifty years. The failures

in the use of ovoparasitic Trichograms against this citrus fruit pest were largely due to improper species identification.

3) The interspecific relationships of biological organisms, such as those connected with competition and polyphagous behavior. Should a beneficial insect be chosen on the basis of being highly pest-specific, or should it be somewhat non-selective in its preying habits (which would in theory allow the insect to better establish itself).

4) The effects as well as the compatibility of other control methods on natural enemies. It is important to note that scientists have found entomophagous insect strains which develop resistance to certain insecticides. Moreover, studies have shown that some pesticide formulations clearly are less toxic than others relative to certain natural enemies.

5) The perfection of techniques concerning the biological control agent's mass rearing, transport, and adaptation.

6) The perfection of methods to distribute or disseminate biological agents in the field. Like the other points, this will require imagination in addition to competence and skill. To illustrate this, let us turn to Canada, where, to control a pine tree defoliator Neodiprion swainei, a plan was developed to infect the pest cocoons with Baculovirus swainei and distribute them throughout the forests. Infected adults emerged from these cocoons, spreading the disease via infected eggs which, in turn, would produce larvae which died in their first stage of development. These larvae, however, would first infect food sources, thereby contaminating the natural insect population and causing death in larvae which had not yet reached the fifth stage. Larvae in this stage would survive, even though infected, and would in turn infect new generations, perpetuating the contamination process.

7) When the application of biocontrol techniques requires villager partic-

ipation, their ability to participate and the information to be conveyed to them must equally be studied.

8) The possibility of altering the biotopes (habitats). Thus, to make a period of high pest infestation coincide with one of effective biological agent activity, a change of planting dates could be a solution. Another example is the raising of islands of beneficial insects within or close to the target crop.

9) Estimating the unwanted effects of using biological control methods. Even though there is less to fear than with using chemical methods, one is still not immuné to all undesirable effects. As seen in the program to eradicate the myasigenic Diptera Chrysomyia macellaria, a cattle parasite, by using the sterile male technique, the deer population increased rapidly, resulting in considerable crop loss. The reason for this was that Chrysomyia was a regulating factor in the deer population as well.

10) An evaluation of the economic benefits to be derived from this control method. This evaluation should take into account the farmer's point of view as well as that of the State. In the implementation of biological control programs, a substantial contribution is often made by the State. This is the efficient aspect of this method, which in general has the advantage of contributing much to national production.

Even though financial benefits are cited last, they must nevertheless be examined from the first, at least concerning those elements which can be evaluated at this time. It must be emphasized that even though applied research seldom shows a return in the short run, it still constitutes a high-return investment, no matter what the form, in the long run. Perhaps one should ask if the researcher who neglects this point isn't taking it too lightly. Also, would it not be of interest for both researchers and development program managers to cooperate in order to study this aspect?

An examination of the problems created by a biological control program teaches us that one must study several areas: phytopharmaceutical, biological, ecological, economic, systematic, sociological, entomological, virological, and nemotological. If researchers could be competent in several of these areas, the depth of study to be conducted would require that a program be conceived which depends on several scientists. This was taken into account by the Integrated Pest Management Project in controlling the pests of principal food crop pests in the Sahel. However, the success of such programs will largely depend upon the spirit in which researchers conduct their work. Moreover, one must not lose sight of the fact that biological control should be combined in the larger field of integrated pest management, which is, itself, only one aspect in the improvement of agricultural production.

If we can find the personnel to carry on biological control research, we must also find sufficient means. For these means, one must be able to sensitize, and therefore inform the powers that be. From this it must not be concluded that limited means cannot bring about results in a biocontrol program. Imagination can, in some cases, offset the lack of material. On the other hand, the program must be designed to the means at hand, remembering that if these cannot be raised, then returns can be by raising productivity (it is in this situation that researchers must redouble their efforts). I would like to warn researchers by reminding them that in developing countries, applied research does not have as its goal a scientific study, but rather, a useful study. I would even pose the question of whether a study which never goes beyond being a report or a publication is indeed not partially wasted.

Since we have here assembled persons in direct contact with **both** development organisms and scientists, let us hope that the former, through their efforts to find effective solutions to crop protection problems, put pressure on the latter group so that they apply themselves to furnish such solutions.

After this brief sketch of the constraints upon biological control, which will be elaborated upon and discussed in several exposés and treatises by different spokesmen, and in order to create an "atmosphere of biological control", you are now invited to view an excellent film on this subject, put out by C.S.I.R.O. (Commonwealth Scientific and Industrial Research Organization).

BIOLOGICAL CONTROL

There is an enormous number of species highly adapted for survival; They have continuously asserted their rights to feed upon crops, foods and foods reserves and to live on domesticated animals and Man himself. But not all insects are harmful; among the beneficial species are those living at the expense of insects which are troublesome to us . Biological control is the restriction of the number of an animal or plant by natural enemies and this film illustrates some aspects of the study of natural enemies and their use in the control of insect-pests.

The Cottony Cushion Scale is native to Australia. It is not a pest in this Country because it is controlled by its natural enemies. But it became a serious pest of citrus in many other countries when accidentally introduced into them.

In California, it nearly destroyed the Citrus industry. One of its natural enemies in Australia is the Ladybird (Rodolia). Both the adult and the larvae eat the scale and its eggs; natural enemies sent from Australia saved the Citrus industry in California and many other countries.

Here the Ladybird larvae have become covered in the waxy covering of the host they are eating. This is a celebrated example of biological control; an insect of no importance in its homeland became a pest in another country where there were no natural enemies to keep it in check; when its enemies were also brought from the Homeland, the insects soon dwindled to negligible numbers. The cabbage moth came to Australia from Europe, unaccompanied by its natural enemies; it soon became a pest...

The eggs of the cabbage moth hatch in a few days and the caterpillars feed on cabbages and related plants; the full grown caterpillar spins the cocoon.

It then transforms to the pupal stage and within a week or two, the moth emerges. Often major parasites attack such accidentally introduced pests but usually they are not very efficient in-controlling them. Hymenobosmina is a native parasite. Such parasites develop from an egg laid within the body of the insect they attack. A larva hatches from the egg and consumes the host.

Hymenobosmina is not an efficient controlling agent for these pests, and so, a more efficient parasite, Heregenes, was introduced from Europe. The females of this species spend most of their time hunting for cabbage moth caterpillars. Like Hymenobosmina, Heregenes is a solitary parasite; (that is, only one can develop in each host). The parasite injects its egg into the body of the caterpillar by means of a fine tube called on ovipositor.

By dissecting the host, we can see through our microscope the eggs of Herogenes. The parasite lives in the tissues of the host, which nevertheless continue to develop. However, once the caterpillar has spun its cocoon, the parasite consumes it entirely. The parasite constructs its own cocoon inside that of the caterpillar. The empty skin of the host is at one end of the cocoon. In a week or more, according to temperature, the

the parasite develops to the adult stage and emerges.

This is Thyraella, another introduced natural enemy of the cabbage moth; it also is a parasite of european origin, but unlike Herogenes, it attacks the pupal stage of the host. The cocoon is an awkward destruction to the female parasite.

She has now succeeded in inserting her abdomen into the cocoon and in inpecting an egg into the pupa, which cannot escape. From the egg, an adult Thyraella develops within the pupa and eventually, an adult parasite emerges. Hymenobosmina, Aerogenes and Thyraella are primary parasites, living directly upon the hoot-insect. But there are secondary parasites which attack the primary parasites, and in biological control, it is important to distinguish between them because secondary parasites tend to reduce the efficiency of the control provided by primary parasites. Eupteramalus is an Australian secondary parasite; it oviposits in the primary parasite of the cabbage moth.

Eventually, an adult Eupteramalus emerges. So, from the cocoon of the cabbage moth, may emerge a moth, or a primary larval parasite, or a primary pupal parasite, or a secondary parasite. Another form of parasitism - egg parasitism - is shown by Microphanurus . a parasite of the green vegetable bug. The bug feeds on tomatoes, beans and many other plants. It deposits its eggs in masses on the underside of leaves. Egg laying is a slow process.

The egg mass is now complete; during development, the eggs change color; the two pale eggs are infertile. The nymphs at about the same time. Their moths can change color several times during development. While young, the nymphs are gregarious. They disperse to feed during the day, but reassemble to rest at night. As they grow older, they lose the gregarious habit.

Several natural enemies of the green vegetable bug have been brought to Australia. <u>Microphanurus</u> is one of them; it is a parasite of the eggs. Notice how the parasites examined the egg; with its antennae, the female can tell if an egg is already parasitized. It drills through the host with its ovipositor and inserts an egg.

Now it marks the eggs, it will know later that this egg is already parasitized. It takes several weeks for the parasite to reach maturity within the host-eggs. <u>Microphanurus</u> is a solitary species (only one parasite developing in each egg). This parasite is in the late pupal stage. The males which emerge before the females contest for possession of the egg - mass. The successful male awaits the emergence of the females. Each female is fertilized as she emerges. The female immediately begins searching for an egg-mass of the green vegetable bug. She is capable of ovipositing immediately. As the female can distinguish between parasitized and unparasitized eggs, she does not waste eggs in hosts which are already parasitized. Not all parasites are solid species; some inject many eggs in one host and the larvae live gregariously within it. This is illustrated by two parasites of the cabbage white butterfly which first reached Australia in 1939; it soon became a serious pest.

This is a young caterpillar of the cabbage white butterfly; to control it, the parasite Apanteles was introduced from the Northern hemisphere. The parasite inserts its ovipositor into the caterpillar and deposits many eggs. Dissection of the caterpillar shows under the microscope the eggs of the parasite. There are often more than fifty of them (50). A dissection of the host at a later stage shows the young larvae living together harmoniously. They feed on unessential tissues and the caterpillar is able to continue to feed and grow. The full grown host is crammed with the parasites . When fully fed, the parasite larvae emerge together through the body-wall of the caterpillar. Each larva immediately spins a cocoon. The caterpillar-their host for a few weeks dies soon after the parasites have emerged. The Apanteles larvae pupate within their cocoons; eventually, the adults emerge and the parasites cycle continues. Many cabbage white butterfly caterpillars in Australia are killed by this parasite - Apanteles. Those which escape are often attacked by another introduced species - Pteramalus - which lays its eggs in the pupae. If Pteramalus encounters a full grown caterpillar, it trails it and waits with it until it pupates; the parasites may have to wait for days.

Here, the caterpillar is spinning the belt which will hold the pupa in position. Meanwhile, the parasites wait.

At last, the host has pupated, and the parasite instinctive wisdom is rewarded. two females are depositing eggs. Pteramalus is a gregarions speies; there is enough food in each host for many larvae. Dissection later shows the full grown parasite larvae. The parasite pupates within the pupal of the host and the adult parasites emerge together through the same hole.

All these parasites develop within the one host. The habits of parasites are closely related to the biology of their hosts. A good example is the parasite Tersilochus and its host - the vegetable weavil which come to Australia from South America. The vegetable w-evil has only one generation a year. They are inactive during the summer months but become active in autumn when they feed voraciously to permit development of the ovaries.

This insect is dispensed with males. All individuals are females; their eggs develop without being fertilized. The eggs are dropped in damp places; The larvae also require a damp environment; they hide away in the day and feed at night. To combat the vegetable weevil, several species of Tersilochus have been introduced from Uruguay.

They are solid-reliable parasites; the larvae of the vegetable weevil, when full grown, burrow into the soil.

They form ova themselves in which their further development takes place. The unparasitized individual pupates and eventually gives rise to an adult weevil. The parasitized individual is consumed by its parasite which then forms a cocoon. The adult parasite emerges from a pupa but remains inactive within the cocoon for five to six months over the summer period. By these unusual means, the large cycles of the parasites and its hosts are kept in phase. The Tersilochus adult issues from its cocoon on a warm winter day. By this time, host larvae are again present for parasitism. This parasite is well adapted to its host. Biological control is more likely to be successful against pests of foreign origin. But when a native pest such as the Queenland's Fruit fly is of particular economic importance, and its natural enemies are ineffective, an attempt may be made to control it by introducing from overseas the natural enemies of closely related pests. The first step enabling to achieve biological control is the study of the insect's biology. The Fruit Fly lays its eggs in groups just below the surface of the fruit.

The eggs can be dissected out and observed through the microscope. Queenland's Fruit Fly causes serious damage to many kinds of fruits. When the larvae become full grown, they leave the fruit and enter the soil to pupate. Later, the flies emerge. There are several generations each year. Because the natural enemies of the Queenland's Fruit Fly are eneffective, let us go to Hawaï, and look at a related pest, the Oriental Fruit Fly. The Oriental Fruit Fly was accidentally introduced from Asia into the Hawaï island during the last war. There, it caused tremendous damage to fruits of many kinds. Hawaïan entomologists collaborating with their colleagues from Mainland USA undertook an intensive study of the Oriental Fruit Fly problem, particular attention being given to the possibility of biological control.

They explored many parts of the world , for natural enemies of Fruit Flies. They found many parasites and several of these have been most useful in reducing the population of the Oriental Fruit Fly in Hawaï. This research was an interesting example of biological control, in which Hawaï entomologists have long played a notable role.

Reports of the effective control of the Oriental Fruit Fly, by Opius Oophilus - another parasite led to an investigation in Australia into the possibility of employing this parasite effectively against the Queenland's Fruit Fly.

Opius Oophilus is the only known parasite which lays its eggs in the egg of the Fruit Fly. The minute egg is passed town the fine ovipositor tube into the Fruit Fly egg where it remains dormant for a while.

This is Opius Longicaudatus, another Fruit Fly parasite. It oviposits in the larva of the Fly. Here, by laboratory devices, we can see Longicaudatus probing fruits with its ovipositor in search of Fruit Fly larvae. It was found that the principal parasite of the Oriental Fruit Fly can also parasitize and develop in the Queenland's Fruit Fly. In Biological control investigations, it is necessary to devise techniques for rearing the posts and its natural enemies.

In the Laboratory, Queenland's Fruit Flies regularly deposit their eggs in bananas.

The bananas are being exposed in a cage to the parasite. oophilus.

The female parasite oviposits in the Fruit Flies eggs embedded in the bananas. After several hours, the bananas are removed; they are cut up and placed on the surface of a food medium which has a carrot base.

Later examinations show that the Queenland's Fruit Fly eggs have hatched and the larvae containing parasites are developing satisfactorily on the artificial medium. The matured larvae are connected when they leave the medium.

They burrow into sawdust and pupate. It is only at this stage that the parasite develops rapidly, consumes the Fruit Fly pupae and automatically becomes adult inside the pupa- cases of their hosts.

Later, parasites emerge from some pupae, and Fruit Flies from others.

Some eggs exposed are not parasitized; although oophilus and other parasites were reared in Australia on the Queenland's Fruit Fly, it was not easy to obtain the large numbers required for release in the fields; in such cases, it is sometimes better to import large numbers for liberation.

The Oriental Fruit Flies contain Opius Oophilus bred in Hawaï.

The parasites will be liberated in Queenland's and used as ways against the Queenland's Fruit Flies.

Great care is taken to prevent the accidental inclusion of any other insect in the consignments . In Hawaï, the insects are anaesthetized with carbon dioxide and examined before being packed for air freighting. The insect quickly recover from the anaesthetic when replaced in a carton. On arrival in Australia, all consignments go to quarantine laboratories for a further check whether other species are not placed among the parasite ones. Everything except the parasites themselves is destroyed. An anaesthetic is injected into the carton to immobilize all the insects while still given a critical examination. Each specimen is identified individually. Any extraneous insect will be dealt with at this stage. The parasites are kept and expertized during the inspection by a flow of carbon dioxide through a hole in the bottom of the inspection tray.

The parasites are sent by air to Fruit Fly areas for liberation.

The factors affecting the ability of natural ennemies to control the pests are extremely complicated and the results of such introductions cannot be forecast. Liberation in the fields is the only sure test of capacity to control. Here, parasites are released on a loquat infested with Fruit Flies. Parasites liberations are preferrably made where crops have not been sprayed with insecticides, which are often as lethal to the natural enemies as to the pests themselves. Sometimes after liberation, the area must be revisited to check whether the parasites have successfully reproduced into the fields. Fruits infested with Queenland's Fruit Flies are collected and sent to the laboratory. In the laboratory, the samples are examined, recorded and stored in sawdust for subsequent emergence of insects. When the emerged insects have died, they are removed and counted. In this instance, the parasites have reproduced in the fields and both parasites and flies are recovered from the sample. Detailed records of the recoveries are made and the specimens are preserved.

Biological Control Problems.

An easy success is not often obtained" Many insects pests to control by the use of insecticides, the pest often becomes resistant to the insecticides used to control; also, insecticides sometimes come up with other pests by destroying the natural enemies to keep them under control.

For such reasons, entomologists are becoming increasingly interested in the possibility of using diseases in place of chemicals for insects' control sprayers. This is a suspension of virus particles of the Granulosis virus found in Australia. The tube holds billions of virus particles obtained from the body of cabbage butterfly caterpillars that have died of a disease. In laboratory tests, a small quantity is taken from the tube and diluted in water and the leaves dipped in the suspension.

Cabbage Butterfly Caterpillars feed on the leaves and so ingest the virus particles. The virus multiplies with great rapidity and the first symptoms of the disease are inactivity and lack of appetite. The caterpillars then become rather pale, the segmentation more distinct and the skin shiny. The disease is extremely virulent and the caterpillars invariably die, often within a few days. They usually become cream-coloured before death.

Afterwards, the body becomes mottled and there is much exuded eggs. Experiment has shown that an outbreak of this disease persists for the duration of the cabbage crop. Diseases of insects are generally quite safe, as Man and domesticated animals are not susceptible.
The "vagi" remains quickly disintegrate when exposed to the weather and the billions of virus particles are freed to infect other caterpillars. In the last stages, the contents of the body liquify and the skin becomes very tenuous. The body and content become black. Insect disease provides a new weapon in the biological control armoury.

It is not to be expected that Biological Control will solve all problems; nor easy successes be looked for. But, when effective, Biological Control is easily the best and cheapest method.
Greenhouse white flies, for example, have ceased to be a problem of any importance, since the introduction of the parasite - Encarsia. The white Fly lays its nymphs on the leaves ,surface within a few weeks, the nymphs hatch out and these are attacked by the parasites. The parasitized nymphs turn black. The Wooly Aphid, once a serious pest of apples was greatly reduced in importance by the establishment of the parasite Aphilinius.
Research is to learn success and combat the insect pests. The problems which insects present are fairly simple but there is always a great interest in practical importance. Among the most fascinating of these problems are those concerned with utilisation of natural enemies and their hosts for the theory and practice of Biological Control.

A Brief Review of Biological Control in the United States Department of Agriculture

by

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For presentation at the USAID-SAHEL Food Crop Protection Project -
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When I was a student at the university in the 1950's, biological control in the United States was represented by a handful of scientists at three or four Federal laboratories and at about an equal number of State universities throughout the country. The apparently miraculous control achieved by DDT, BHC, TEPP, as well as a long list of other new pesticides, seemed to have signaled the demise of biological control in all but a few areas of research. However, as we are all well aware, the miraculous effect did not last forever. Pest resistance, environmental pollution, health hazards and the like appeared, and the search was on again for methods of controlling the pest organisms.

The public became aware of the possibilities of biological control. Federal and State organizations increased their support for new research with natural enemies and biological control began to grow. Today there are more than 150 scientists conducting research with natural enemies at 62 USDA laboratories throughout the United States and at four permanent laboratories overseas.

Most of the research in biological control within the Federal Government is under the jurisdiction of Agricultural Research, a component of the Science and Education Administration, an agency of the USDA. Within Agricultural Research itself, there are several National Research Programs. These programs provide the basic plans for research within Agricultural Research. One of these National Research Programs is responsible for the research with "biological agents for pest control." Under this program there are 15 domestic laboratories and four overseas laboratories, all of which are involved in some aspect of biological control.

The four laboratories in the foreign countries are devoted entirely to the search for natural enemies of exotic insect and weed pests in the United States. The oldest laboratory, established in 1919, is the European Parasite Laboratory located in Sevres, a suburb of Paris, France. It is primarily concerned with natural enemies of insect pests. In 1975, the Asian Parasite Laboratory was established in Sapporo, Japan, also for research with insect pests.

The research with weed-feeding organisms in Europe and the Middle East is done at the Biological Control of Weeds Laboratory that was opened in Rome, Italy, in 1959.

In 1962, a Biological Control of Weeds Laboratory was established in a suburb of Buenos Aires, Argentina, to search for natural enemies of the aquatic weed, Alternanthera philoxeroides. Today, this Laboratory is involved in a large number of projects with insect pests, in addition to the regular program of weed research.

Within the United States, some of the domestic laboratories are concerned only with insect pests, others only with weed pests, and others study pathogens for use as biotic agents or as pest organisms.

All exotic organisms destined for use in the United States as biotic agents must enter the country through a quarantine receiving station. Within the USDA, there are five such receiving stations. Two of these facilities deal exclusively with arthropod pests and their natural enemies. These are located in Newark, Delaware, and in Columbia, Missouri. In California, the Biological Control of

Weeds Laboratory is the entry point for most phytophagous arthropods. In Mississippi, the Quarantine of Insects Research Laboratory has facilities to work with both entomophagous and phytophagous arthropods. Recently, it has been authorized to conduct research with exotic plant pathogens.

At Frederick, Maryland, the Plant Disease Research Laboratory conducts research with exotic plant pathogens as potential agents for weed control. All these quarantine laboratories have the responsibility to screen incoming material and eliminate any contaminants, conduct any additional research necessary to clear the organism for entry, obtain or confirm the identity of the organism, and to prepare and ship the natural enemy to cooperating research laboratories. In addition to their quarantine operation, these laboratories have research scientists who conduct indepth studies with the exotic agents.

Once the beneficial organisms are cleared for entry and release in the United States, they may be (1) retained at the station for continued studies; or (2) sent to other USDA laboratories in the country; or (3) released to various State and university laboratories for their research purposes; or (4) released in nature. As a result, there is often considerable cooperation between the Federal, State, or university research institutions. This cooperation results in a concentrated research effort being directed to the use of one or more beneficial organisms from a foreign source.

In addition to "classical" biological control, which consists of introducing exotic organisms to control pest species, there is a considerable amount of research in progress at other Agricultural Research laboratories that addresses other aspects in the field of biological control. For example, at the Agricultural Research laboratory in Fresno, California, there has been a great deal of work with parasitic nematodes for the control of *Leptinotarsa decemlineata*, the Colorado potato beetle, various mosquito species, and wood-boring moth larvae attacking native trees.

In Tifton, Georgia, scientists at the Southern Grain Insects Research Laboratory are experimenting with the use of body odors, or kairomones, emanating from plant-feeding insects. These kairomones have been demonstrated to attract natural enemies of the insect pest. Possibly, these odors can be synthesized and utilized for insect control. At the Columbia, Missouri, laboratory, there are experiments in progress to produce flightless insect parasites and predators by exposure to irradiation. The limited mobility of these insects will force them to remain within the fields where they are released, thereby limiting their dispersion and increasing their effectiveness.

In Ithaca, New York, a USDA scientist attached to the Boyce Thompson Institute has demonstrated that the manipulation of a native species of fungus can induce a serious epizootic in populations of native grasshoppers.

Research at the Insect Pathology Laboratory in Beltsville, Maryland, is more basic in nature. Scientists at this location are involved in cell culture and tissue culture techniques, identification studies with viruses, virus-like organisms, as well as with other microorganisms.

The list of research projects in biological control is too long to attempt any complete review of these activities described in the National Research Program. There are projects that include tests with allelopaths; those physiological chemicals produced by some plants that inhibit the growth of other plants. A similar control method is already in practice in Asia and Africa where a flower, the marigold, is planted in tea, tobacco, and potato fields to control nematodes.

In recent years, there has been a considerable increase in the use of computers to store information relating to the shipment of arthropods, to catalog information concerning museum specimens, and to prepare comprehensive taxonomic catalogs. More and more of the biological control laboratories are using computers to store and retrieve the immense amount of data that is being generated by the research scientists.

Although it is the last to be discussed, it is in no way the least important. I am referring to the SEA-AR Systematic Entomology Laboratory at Beltsville, Maryland. Without prompt and correct identification, the entire structure of the biological control programs would collapse. The identification of the pest species and the associated beneficial arthropods is a cornerstone of the entire program. The same can be said for those projects that are concerned with pathogens and other microorganisms. Without the support of these devoted taxonomists, biological control, as we know it, would cease to be a science.

The activities of these laboratories and others in the National Research Program are not restricted to research that will benefit only the United States. There is a great deal of interaction with other national and international organizations such as the Commonwealth Institute of Biological Control, the Commonwealth Scientific and Industrial Research Organization of Australia, the Institute National de Recherche Agronomique, etc., throughout the world. These activities have consisted of exchanges of natural enemies and information, cooperation in research projects, and other kinds of joint ventures. Agricultural Research laboratories have supplied natural enemies to countries in Africa, Asia, Europe, and South America. Also, the Systematic Entomology Laboratory has identified thousands of specimens for scientists and others from all corners of the world, including Africa. Biological control is international. Without mutual cooperation between scientists, organizations, and countries, there can be little progress.

BIOLOGICAL CONTROL
AT C.E.R.D.A.T.

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RESULTS - DIRECTIONS
SAHELIAN PROBLEMS

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by J.Brenière

Having been invited to speak on the matter of biological control research, such as it is carried out at GERDAT, my exposition will give an overview of, not only concerning research and results obtained at GERDAT institutes, but also of present research, particularly that relating to main food crops in the Sahel region. Unfortunately, one must acknowledge on the outset that knowledge regarding this particular region and these crops is yet very limited. This is why, while setting forth some ideas on both on the difficulties and the acute necessity of concentrating and coordinating research, an attempt will be made to indicate what could be GERDAT's role in carrying out coordinated biological control programs in the Sudano-Sahelian zone.

Research in biocontrol,-or laying ground work to biocontrol-,has been part of post war programs in tropical agronomic research, carried out by French institutes.

As early as 1943, RISBEC set out the inventory of entomophagous insects of crop pests in Senegal. Its work on the entomological fauna of crops in Senegal and the Sudan, published in 1950, is still considered a reliable reference.

At the same time, in Madagascar, FRAPPA introduced a parasite of eucalyptus weevil ; thanks to this, the terrible forest menace was wiped out, thus paving the way for reforestation of the Madagascar high plateaus.

In the fifties and sixties (1950-68) MIAR, (Madagascar Institute of Agronomical Research) launched the biological control of sugar cane borers. To combat CHILO SACCHARIPHAGUS, a number of studies of the pest's biology and ecology, as well as of its natural enemies, were conducted. An i digenous trichogrammidae, T.AUSTRALICUM, although found in great abundance at the height of the infestations, seemed worth exploiting. Mass rearing was carried out; however, experimental flooding releases in several areas brought out the fact that the trichogrammidae was incapable of exceeding natural reproduction levels. Another species, T.FASCIATUM, which was introduced from Central America, produced no better results.

In 1963, ITAR (Institute of Tropical Agronomic Research) which was then in the process of taking over the activities of MIAR, undertook the difficult task of introducing an Indonesian tachinid fly, DIATRAEOPHAGA STRIATALIS. This action culminated in perfecting mass rearing; numerous releases were possible and were carried out on Madagascar and on Reunion islands. However, after five years of releases under varied conditions, we were forced to recognize the fact that the insect could not weather the cold season, therefore could not adapt .

These two successive failures were fortunately compensated by a success : the introduction of APANTELES FLAVIPES to Madagascar, which took place in 1960. Be the following year, this braconidae had spread to all sugar cane crops in the North West. Three years later, firmly established, it brought about an extremely positive balance in the control of sugar cane borers.

Tobacco followed sugar cane as the object of biocontrol. Still on Madagascar, from 1970 to 1972, five parasites of the tobacco and potato moth GNORIMOSCHEMA OPERCULELLA were introduced. Of these, APANTELES SUBANDINUS established itself, parasitizing 20 to 70% of all larvaes and spreading in abundance in areas quite distant from release points.

Again in Madagascar, in 1968 and 1969, the eulophidae PEDIOBUS FURVUS was introduced to combat maize sesamie. It established itself throughout the island, reducing the pressure effects of this pest.

On Reunion, in 1962, ITAR set up a biological control laboratory, under the direction of Dr. Etienne. Since its inception, numerous entomophagus insects have been introduced: the aforementionned parasites of sugar cane borers, as well as numerous parasites of trypetidae pests of fruit and vegetables.

We must mention also the introduction on Reunion of TETRASTICHUS DRYII which totally eradicated the citrus psylla TRIOZA ERYTREAE, greatly reduced mealy wing infestations of aleurode ALEUROTHRIXUS FLOCCOSUS.

However, we are getting away from the problems of continental Africa, which shall now be examined .

The ICTR (Institute of Cotton and Textile Research) has long been active in the process of biological control in Africa. Inasfar as cotton chemical treatments in several areas created imbalances in the biocenosis, favoring insects which, until then, had been rare or insignificant. Moreover, primary pests ended up becoming resistant to an ever growing number of pesticides, while beneficial insects disappeared. This is why a super abundance of the cochneal FERRISIANA VIRGATA has been observed, and more recently, infestations of mites and aphis.

In Northern Cameroon, DIPAROPSIS WATERSI is the primary cotton pest, due largely to its strictly monophagous behavior.However, it is kept in check by a tachinid fly (EUCARCELIA E VOLANS), which has reached up to 30% of parasitism. ICTR has studied the means of protection necessary to assure the survival of this beneficial insect, despite pesticide treatments. Following determination of the trachina s habits in relation to its host's diapause, an artificial food source was found which could assure mass rearing of DIPAROPSIS. Large scale reproduction and releases of the tachinid fly could then be envisioned.

Another parasite which has been introduced is the oophagous TRICHOGRAMMA BRASILIENSE . It has been reared and distributed in several West African countries and in Madagascar. This beneficial insect has adapted well to the eggs of HELIOTHIS and of EARIAS; its role is however still limited to experimentation.

At the same time as research is being conducted on entomoganous insects, ICTR is also studying entomopathogenes. Several research stations have undertaken specialised field studies and possess adequate laboratory equipment. Among these are the Bouake (Ivory Coast) and **Bebedjia** (Tchad) stations, where entomopathogenical research and inventories have beeen carried out for years; the polyedrosis HELIOTHIE ARMIGERA and the granulose CRYPTOPHLEBIA LEUCOTRETA are now being reared and experimented with in the field.

In Maroua (Cameroon), in addition to the study of local entomopathogenes, ICTR has initiated laboratory research on the effectiveness of autochtone viral strains (Pathogeneic effect of viri of MAMESTRA BRASSICAE, of AUTOGRAPHA CALIFORNICA, of SCOTIA SEGETUM and of GALLERIA MELLONELLA virus on DIPAROPSIS WATERSI) which is complemented by field experiments of the polyedroses of MEMESTRA BRASSICAE and of HELIOTHIS ARMEGERA.

In France, these projects have received technical and scientific assistance, as well as cooperation from the NIAR laboratories in St.Christolles Ales in identifying (sero agglutination and electrophoretic diagrams of DNA), and in La Minière for technological and application method questions.

Finally, BACILLUS THURINGIENSIS has been experimented with, with some positive results, on cotton leaf pests.

For several years, researchers have known about the pheromone HELIOTHIS and in the process of perfecting that of CRYPTOPHLEBIA LEUCOTRETA. Experiments are now being carried out concerning trapping methods and the uses that could be derived therefrom.

In Mauritania, between 1966 and 1968, the FCRI (Fruit and Citrus Research Institute), undertook a far reaching program against a main pest, PARLATORIA BLANCHARDI (date & palm scale).

The predatory coccinella CHILOCORUS BIPUSTULATUS var. IRANENSIS was introduced and multiplied from a stock taken from Iran. It was soon shown to be an extremely active predator. It quickly established itself, particularly in the date palm orchards of the Atar region, reducing the scale to negligeable levels in a matter of a few years.

The other Sahelian crops, which are essentially food crops, usually do not generate much production. Unlike the cotton farmer, the villager having limited resources, cannot afford the cost of insecticide treatment. a solution both costly and eventually dangerous. Control of insect pests, then, must be mainly accomplished by adopting agronomical methods, which best favor plant development. Forms of biological control must be explored, particularly in the field of resistant varieties.

However, to date, very little research on these crops has been carried out leading to practical results and application.

A rapid overview of the entomological problems connected with millet, sorghum and maize, in the Sahelian and Sudanian regions reveals a small number of pests having a considerable economic impact on crops growth.

The following are some of the elements of this nature :

MILLET - is frequently attacked by the pyral's ACIGONA IGNEFUSALIS. Widespread in the entire Sahel, this moth can inhibit or cause the spike to dry up before the grain has matured, this by interrupting the flow of sap in the stem.

This borer has at least twenty natural parasites. Of these, the ichneumonide SYZEUCTUS SP, and the bethylde GONIOZUS SP seem to be the most abundant. ACIGONA goes thru two to three generations during the rainy season. However, as the entomophages typically do not appear until the second generation, and do not multiply in significant numbers except during the height of infestation, it is too late to be effective.

Millet spike caterpillars, which represent several species of RAGHUVA and MASALIA produce only one generation a year and are heavily parasitized. VERCAMBRE studied these insects in Senegal from 1974 to 1976. Following the extremely heavy infestation of 1974, he observed starting in 1975, a marked decrease of this pest and at the same time, a spectacular rise in levels of parasitism and predation. A braconidae, HABROBRACON SP. HEBETOR ? , has even succeeded in parasitizing almost all of the caterpillars surveyed at season's end.

SORGHUM is principally affected by two diptera : the "growth fly" ATHERIGONA SOCCATA and the cecidomyiidae of panniculus CANTARINIA SORGHICOLA.

In Upper Volta, a ITAR entomologist inventoried the sorghum pest species ATHERIGONA, which affects sorghum in a detrimental manner.

He contributed to the research of resistant varieties of sorghum by establishing comparisons between local varieties. It was thus proven that the resistance of varieties already selected for their resistant qualities remained high in Upper Volta, whereas the local variety GNOFING was more sensitive to attack. It is therefore essential to systematically introduce the resistance to ATHERIGONA as one of the criteria for selection when selecting varieties which are adapted to the country conditions.

We have a better knowledge of CANTARINIA SORGHICOLA, thanks to COUTIN's study, carried out in Senegal fron 1966 to 1969. Extremely widespread infestations of sorghum midge are favored by its multivoltinism. or high reproductive capacity (one generation produced every two weeks), and by the mixing of sorghum varieties having different cycles which prolong the duration of earing, that is, the period when the midge can lay its eggs in the flowering panicles. Entomophagous insects were counted : two larvae parasites : EUPELMUS POPA Gir, and TETRASTICHUS DIPLOSIDIS Grawf and the predatory anthocoridae ORIUS PUNCTATICOLLIS Reuter could not effectively slow down the infestation.

Different sorghum varieties have different sensitivities. From the 20 local varieties in Upper Volta, BONZI, in 1979, identified the three most resistant. Varieties # 970 and 174 posess enveloping glumes which do not open at the time of flowering, while # 324 opens normally. The latter, placed in a variety of situations or circumstances, does not seem to be attacked a great deal.

Varietal resistance or sensitivity should then be taken into account particularly in researching late varieties having a long cycle, which undergo the gradual effects of midge infestation. The study of localised varietal properties in the same area should also be taken into serious consideration in relation to the fanning of earing period .

MAIZE - In the case of maize, lepidopterous borers appear to be the most prejudicial. Among these SESAMIA CALAMISTIS, BUSSEOLA FUSCA and ELDANA SACCHARINA are the most frequently encounted. The inventory of their parasites is in process both in Upper Volta and in the Ivory Coast. These polyphagous borers are the object of ecological studies concerning several cultures. This is the case for ELDANA SACCHARINA studied on maize by OSTROM and on sugar cane by ITAR in coordination sugar industries of Upper Volta and of Ivory Coast. Integrate control of this borer, adaptive capacities of several entomophagous INSECTS have been observed in laboratories (LIXOPHAGA DIATRAEAE, PEDIOBIUS PARVULUS, TETRASTICHUS SP., TRICHOGRAMMA SP.) sans having the possibility of adaptation in the field.

R I C E - Of all food crops, rice is the one that has been the one most closely studied by ITAR within the framework of agronomic research of Senegalese and Ivorian Institutes. Predatory pests were inventorized, the most important of them being the prime object of ecological observations in a liaison with research on integrated scale, this being a part of chemical control as well as agronomic and biological struggle. The inventory of entomophages of lepidopterous borers : CHILO ZACCONIUS, MALIARPHA SEPARATELLA, scirpophaga melanoclista, SESAMIA CALAMISTIS is well under way, particularly in Senegal (Casamance) where an ITAR entomologist adds his efforts to those of SARI. The introduction of APANTELES CHILONIS was attempted in Casamance and should be repeated on a larger scale. Other introductions are at the project stage.

Elsewhere, in the Ivory Coast, an entomologist from ITAR is carrying out, within the framework of IDESSA a research program based on the resistance of upland rice to predatory pests ; the multidisciplinary team of which this entomologist is a part is working on varietal improvement of upland rice. First results have clearly indicated differences between local and introduced varieties.

Therefore, I have just given you what is the essential part of the research work carried out by the GERDAT institutes in Africa, in what concerns the biological control of food crops in the sudano-sahelian zone.

To these activities, must be added those in progress in France in Montpellier, in the central institute's laboratories, within the same domaine of biological struggle .

It should be brought out that the exigencies of control operations require non only a perfect knowledge of biocoenosis and its mechanisms, but this background data must be complemented by information on taxonomy of entomophagous insects, by mass rearing techniques for hosts and parasites, by knowledge of natural and synthetic pheromones, by isolation and evaluation of entomopathogenous viral and bacterial strains, and, of course, by thebgathering of documentation on entomophagous insects susceptibles of being introduced.

Fully aware of the diversity of problems and obstacles, GERDAT gathered in Montpellier, not only means, but researchers in order to advance these preparatory endeavors, in view of biocontrol operations .

GERDAT has at its disposal a faunistic service, a laboratory for nutrition and rearing of insects, a cell for the study of entomophagous insects, a laboratory for entomopathogenes and a team of ecologists.

THE FAUNISTIC SERVICE is responsible for a certain share of identifications, this in liaison with Paris Museum. The head of this service is a senior taxonomist, who proceeds with the preliminary sorting out, so that samples could be directed towards the most qualified specialists. Identification of hemenopterous parasites is stressed, but in this field, the small number of specialists is a serious handicap for the desired accurate inventories that are so needed.

THE INSECT NUTRITION AND REARING LABORATORY is in charge of perfecting rearing techniques of pests and their entomophages taking place in an artificial environment. EntOmologists from TCRI and ITAR contribute to this research. Thes procedure is essential to obtain a production of a predator for various uses in large quantities: entomophagous rearing on a large scale, study and control of pheromones, carrying out tests of plant resistance (varietal) in controlled infestation conditions, production of entomopathogenous microorganisms.

It must be kept in mind that to insure the adaptation of an entomophagous insect, tests must be multiplied both in space and in time. As an example, 142.000 units of the Indonesian Tachinary fly had to be released over a period of 5 years before their incapacity of adapting to local conditions could be made certain. In Madagascar, 42 releases of APANTELES FLAVIPES had to be spread out over a period of six months to be sure of its implantation, while dispersed releases had no success a few years before.

Moreover, when we deal with sahelian or sudanese pests having only one or two annual generations, it is important to free the auxiliaries as soon as possible during the period of growth of the population ; to this end, it is useful to have at hand rearings both of hosts and of parasites multiplied in semi artificial or artificial conditions during the preceding dry season.

At the present, what is being under study are the pyrales (moth) and the noctuids (owlet moth) , pests affecting Cotton, Sugar cane and tropical gramineae.

Techniques for mass rearing in artificial environment are now set for HELIOTHIS ARMIGERA, CRYPTOPHLEBIA LEUCOTRETA, EARIAS BIPLAGA, SPODOPTERA LITTORALIS, CHILO ZACCONIUS, C.PARTELLUS.S. CALAMISTIS,DIATRAEA SACCHARALIS, PROCERAS SACCHARIPHAGUS, ELDANA SACCHARINA, HYPSIPYLA ROBUSTA. We have now the facilities to rear these hosts in great quantities, according to need, and to undertake mass rearing of some of their parasites. We have thus bred : GONIOZUS PROCERAE, APANTELES CHILONIS, A. FLAVIPES and studied the adaptive capacities of several hymenoptera and diptera on ELDANA SACCHARINA.

ENTOMOPHAGOUS INSECTS STUDY CELL IS IN THE PROCESS OF DEVELOPMENT .

It is taking the direction of trichograms, work progressing in liaison with the NRRI team of Antibes, under the direction of VOEGELE. This program which started recently, consists in isolating local species of trichogram parasites of cotton borers as well as of gramineae. These strains are compared with the tropical species filed in the NRRI collection, in order to better ascertain their potential.

The study stresses the evaluation of biotic potentials and olfactive capacities of each strain in relation to host eggs .

ENTOMOPATHOGENES STUDY CELL has recently been created to insure the link with tropical countries, to regroup and air material in transit and thus evaluate the joint actions carried out within the different institutions.

At the present, work in this cell is limited to the study of BACULOVIRUS ; this is due to present legislation. Actually, the fact that O.M.S. recognized the NON-pathogenicity of virus (Baculovirus) on vertebrae opens new perspectives for biological or integrated control. The recent discoveries of non specificity of certain viral diseases in Lepidoptera (nuclear polyedroses of Autographa californica, of Mamestra brassicae and of Scotia segetum) widen horizons, since a single and same agent can be applied to a complex of several pests prejudicial to a given culture, such as : SPODOPTERA - HELIOTHIS - DIPAROPSIS in the case of cotton. The same perspectives can be envisioned for food crops (rice, sorghum, maize, etc...) and other crops .

Besides the essentially practical purpose consisting in directing the material towards the most highly specialized laboratories in research on entomophagous bio control, the program of this particular section aims at the outset towards the following activities :

- Exchange and collection of materials concerning BACULOVIRUS
- Participation in a BACULOVIRUS bank of tropical origin.
- First screening of collected species, using sound material coming from feeding laboratory in GERDAT and according to requests.
- Species maintenance and first stage of purification in view of identification (identifications cannot be made by the St.Christol (NRRI) until a certain purification of samples.).
- Study of "protecting" agents, of inclusion techniques, of resistance to U.V. in controlled conditions, this conducted in cooperation with NRRI (La Minière) and in relation with establishments engaged in phytosanitary products.
- Study of attractive and phagostimulating substances that can be used in association with polyedroses , work that can be followed up in relation with the insect feeding laboratory in Montpellier (GERDAT) and the NRRI laboratory for chemical mediators.

ECOLOGISTS TEAM .

GERDAT has also at its disposal a team of ecologists specialized in questions of ACRIDOLOGY. Their work allowed the determination of pullulation conditions in Sahel countries, of acrididae, small migrators called grasshoppers.

The evaluation of ecological factors on which the life of the acridian depends is leading to the identification of constraint factors limiting their development and their pullulations. Working from these elements, it was possible to establish an ecological modelisation leading to a prevision model. Applied to several cases, mainly to OEDALEUS SENEGALENSIS, LAUNOIS is able to explain the apparition of pullulations and thinks he can make the model to be exploited in view of prevision and organisation of control.

Although this team had no opportunity to work towards biocontrol, it can apply its results to other problems besides acridology. It has the means of assembling elements of a given agrobiocenose, to analyse its constraints, and bring out essential approaches of an integrated control.

WORK IN PROGRESS AT GERDAT REGARDING BIOCONTROL IN SAHELIAN REGIONS.

We just gave you a picture of the means available to GERDAT in Montpellier.

As to Sahelian zone, GERDAT has two entomologists (ITAR) for food crops and five for cotton (TCRI).

These research workers are integrated with national institutions, which are SAR in Senegal, the Ministry of Scientific Research in Upper Volta, the Institute of Rural Economy in Mali and the Institute of Agronomic Research in Cameroon .

In what concerns RICE, studies are made essentially on the biology and ecology of pests, on establishing the inventory of entomophagous insects and their economic role, this in liaison with GERDAT of Montpellier ; also introductions of foreign entomophagous insects that can implant on lepidopterous borers of rice. Linked to the selection, varietal sorting out relative to resistance to main pests is carried out.

In Upper Volta, the program is mainly concerned with the Sorghum midge (cecidomye) ; varietal resistance is sought, working as a team with the selector.

The same thing occurs in what concerns the FOOT FLY : Atherigona soccata.

Inventory of maize insects is in progress, in liaison with research workers from GERDAT and ORSTROM from the Ivory Coast.

In what concerns COTTON , aspects of biocontrol carried out by TCRI are mainly directed on entomopathogenes ;

These include; experimentation in the field of a combination of granulose (CRYPTOPHLEBIA) and of two nuclear polyedroses (HELIOTHIS ARMIGERA and SPODOPTERA LITTORALIS), which is taking place in Bouaké (Gold Coast).

In Maroua (Cameroon), experimentation is applied on the association of two nuclear polyedroses, that of MAMESTRA BRASSICAE which acts on DIPAROPSIS WATERSI and that of H.ARMIGERA on the same species. The action of BACILLUS THURINGIENSIS on COSMOPHILA FLAVA and SYLEPTA DEROGATA is studied there, in association with the preceding complex.

All these insects, except D. WATERSI are polyphagous. In the Sahel framework, the study of entomopathogenes is certainly a field worth exploring since it could affect several food crops at the same time (Niébé, Arachids, Gombo, Tomatoes...)

Trichogrammidae research is an area of study in which GERDAT is involved both in the field and in laboratories in Montpellier. In the region of Kaolack, in Senegal, a part time researcher is prospecting local trichogrammidae and is setting up rearing of species with the objective of defining parasiting capacities of these strains concerning D. WATERSI on cotton, RAGHUVA on millet CHILO SP. on rice and H. ARMIGERA on cotton and associated crops.

At the present stage, the program is limited to the study of biotic and adaptive capacities of these species in comparison to other strains of a foreign nature. In cooperation with CILSS and the Center for horticultural development of Camberene, a preliminary study of control possibilities of HELIOTHIS ARMIGERA populations is planned, applied to tomato crops thru successive releases of trichogrammidae; the selection of these will be defined following results of studies under way in Montpellier.

Finally, in matter of PHEROMONES , we started, with the participation of NRRI laboratories specialised in chemical mediators, research on synthesis analogous of pheromones from CHILO ZACCONIUS, CRYPTOPHLEBIA--LEUCOTRETA, HELIOTHIS ARMIGERA..... EARIAS BIPLAGA, SPODOPTERA LITTORALIS, DIPAROPSIS WATERSI, HYPSIPYLA ROBUSTA.

Production of several pheromones of synthesis is under way. This study is to be continued as of this year thru experimentation in the field with products obtained.

To this enumeration of work under way, must be added actions that we could undertake according to needs and if means were available. GERDAT does actually have at its command specialists in fruit crops (NRRI)-(Fruit and Citrus Research Institute); these could get under way or follow up operations of biocontrol against citrus cochineal found in great numbers in sahelian regions.

It will be noticed that, within the entirety of operations, ~~that~~ GERDAT's particularity is mainly found in the close liaison between actions in the field and basic research taking place in laboratories, mainly in Montpellier.

In fact structures, services and laboratories in Montpellier can only find their justification in programs effective in the field.

If our working apparatus is in process of growth in Montpellier, it must be noted that it remains rather weak in Africa particularly in the Sahel .

WHAT CAN GERDAT CONTIBUTE TO COOPERATIVE BIOCONTROL PROJECTS :

GERDAT's setup can find its place within the framework of bilateral or international cooperative projects in which a fair repartition of means and programs would allow each, according to competence and structure, to bring its share. (see Table attached)

In the case of control by means of entomophagous insects, GERDAT is able to contribute thru participation to inventories, the perfecting of mass rearing techniques, particularly in artificial environment, which affords an abundant production at any time of the year.

Our Montpellier structure allows us entomophagous multiplications in sufficiently important quantities to enable introductive testing.

The necessary ecological research can be undertaken either by our research workers in the field, or in cooperation with national or international institutes.

However, any entomophagous introduction needs the setting in place of an operation of sufficiently large scale to render it significant. It must be recognized that , to date, means to achieve this were lacking.

Each operation should obtain its own financing, to be distributed among the various partners contributing to the entire operation ; procurement of entomophagous insects - preliminary ecological studies - dynamics regarding relations hosts-parasites-entomophagous rearing and their multiplication - preparation of releases - their execution and control of results -insect diffusion beyond release zones . A similar process applies also to research and application concerning trichogrammidae, pheromones and of course, entomopathogenes .

GERDAT has the necessary means to participate in such entreprises together with its African partners, this goes without saying, but also within the framework of international plans of assistance.

More specifically, in what concerns research in varietal resistance, our small team can find its place in a larger program, particularly ICRISAT in the matter of sorghum resistance to CANTARINIA and ATHERIGONA .

For RICE, research is in progress in conjunction with ADRAO .

The foregoing is therefore a brief summary, without getting into details, of GERDAT possibilities and choices in what concerns biological and integrated control of sahelian crops .

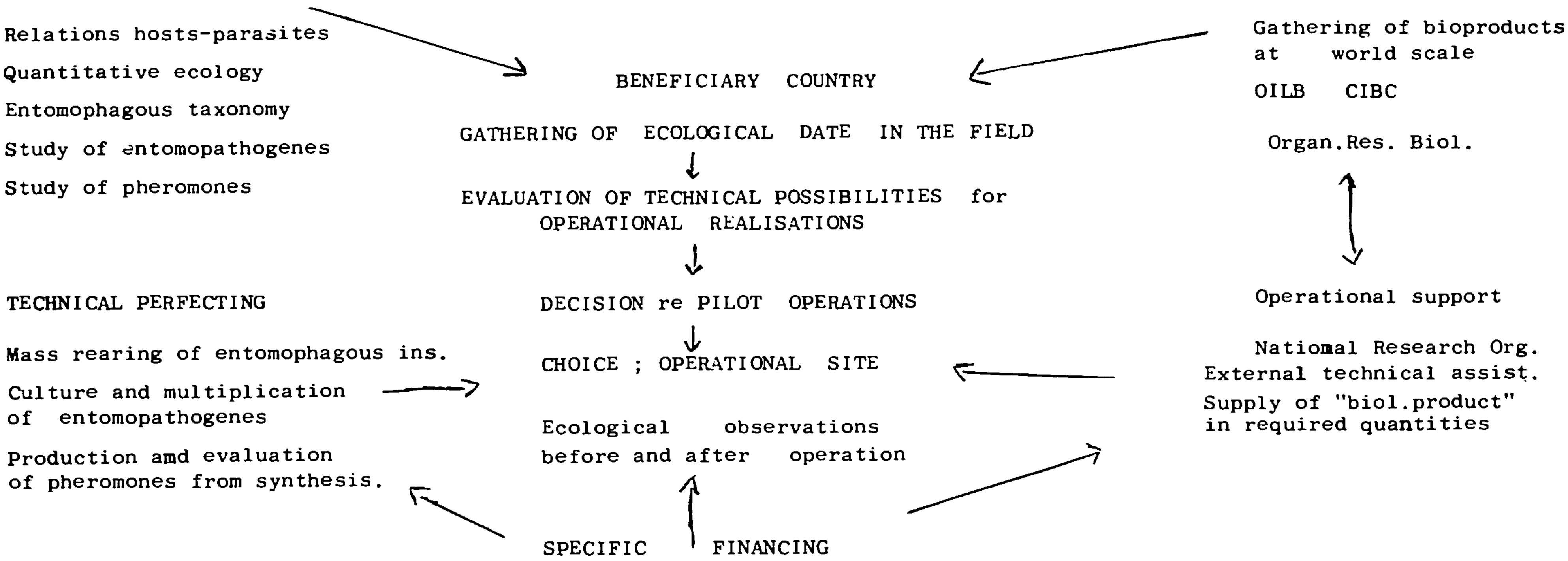
What we can offer is not negligible, but yet insufficient to bring out within a short term the beneficial effects of biocontrol. Cooperation in this domain is highly desirable so as to gather available means to be directed towards limited objectives.

We need to prove that biocontrol can bring real economic improvements in these countries, not only beautiful theories pleasing to intellectual ears but sterile for farmers.

The task ahead is long and hard but we are only at the very beginning ; it is therefore essential to double up efforts, gathering forces from all those who can contribute to research, structure and of course, financing.

For the time being, it is urgent to find out whether we can hope to see on the African continent, such improvements as would follow introductions of entomophagous insects originating from other continents. We do not know as yet what could be applications of pheromones on food crops . We dont know, but could have better chances of success, what could be the effect of varietal improvement , keeping in mind resistance to insects.

The road ahead is wide, too wide maybe, it therefore, should be channeled



BIOLOGICAL CONTROL - OPERATIONAL PLAN

Entomophagous insects -
ENTOMOPATHOGENES

BASIC RESEARCH

Relations hosts-parasites
Quantitative ecology
Entomophagous taxonomy
Study of entomopathogenes
Study of pheromones

TECHNICAL PERFECTING

Mass rearing of entomophagous ins.
Culture and multiplication of entomopathogenes
Production and evaluation of pheromones from synthesis.

BENEFICIARY COUNTRY

GATHERING OF ECOLOGICAL DATE IN THE FIELD

EVALUATION OF TECHNICAL POSSIBILITIES for OPERATIONAL REALISATIONS

DECISION re PILOT OPERATIONS

CHOICE ; OPERATIONAL SITE

Ecological observations before and after operation

SPECIFIC FINANCING

INTERNATIONAL RELATIONS

Gathering of bioproducts at world scale
OILB CIBC
Organ.Res. Biol.

Operational support

National Research Org.
External technical assist.
Supply of "biol.product" in required quantities

- Technical and scientific conception coming from a qualified research organism.
- Interventions in the field.
- Research and technical realisations that could be effected by (or in collaboration with) :

organisations engaged in most specialised basic research (Museum. University, etc..)
" technical assistance)GERDAT, ITAR , etc...)
" national research in benefiting countries.

GTZ - PLANT AND POST HARVEST PROTECTION PROJECTS - WORLDWIDE

Carlos Klein-Koch and Ludwig Luchtrach

Summary

The establishment and background of the Agency for Technical Cooperation (GTZ) are described. It is pointed out, that by the way it functions, it cannot follow a specific strategy of biological control. However there is a tendency by the Third World partners to emphasize the integrated way of pest control. Therefore the major part of the project activities are supported by the idea of pest management. Different aspects of plant and post harvest protection projects are discussed.

GTZ = Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), Gmbh
German Agency for Technical Cooperation, LTD., (GTZ)
Office Allemand de la Coopération Technique, SARL (GTZ)

The German Agency for Technical Cooperation, was founded in 1975 by the Federal Ministry of Economic Cooperation (BMZ). It substitutes the former GAWI.

The idea to create an agency with limited liability by the German government was to permit the GTZ to react more readily to the requirements and to work more economically to the benefits of its partners by employing their extension workers as contractors and not as governmental officials.

About 2 000 employees are now working in this agency, two thirds in worldwide projects and one third in the administration in Eschborn in the outskirts of Frankfurt. The agency functions in general as a service entreprise. It is offering technical aid under the government of the Federal Ministry of Economic Cooperation, i.e. it reacts mainly to requests from Third World partners. However on a small scale it is also involved in what is called "business with thirds", i.e. projects in countries who pay directly for the services (e.g. Saudi Arabia).

.../...

There is a long list of different activities throughout the world. The discussion will be focused on plant and post harvest protection projects, which play one of the major roles in the framework of agricultural technical cooperation offered by the Federal Republic of Germany. The total German contribution amounts to over 50 million Dollars.

Since the GTZ reacts only to impacts from other countries, there is no specific strategy in following a special philosophy of plant and post harvest protection. Therefore the projects are designed to meet the different requirements of each country, usually establishing or promoting the national plant protection service. This includes advice, development of early warning systems, furnishing of spraying equipment, vehicles and insecticides.

Under this general aspect is included the major part of the 26 GTZ plant and post harvest projects e.g. in Morocco, Nicaragua, Niger, Nigeria, Philippines Togo, Tonga, Yemen etc.)

On the other hand there are the more specialized types of projects like the Water hyacinth control in Sudan, the control of the Rhinoceros Beetle (Oryctes rhinoceros) in Western Samoa or the coffee rust (Hemileia vastatrix control in Columbia.

However, there is a world-wide tendency to minimize food losses by means of integrated pest management. Therefore the GTZ started programs aiming at the use of more specific pesticides and at the introduction of parasites and predators from other countries to support the natural antagonistic potential balance the attack of pest populations and thus raise the economic threshold.

Among the integrated pest control cooperation come the profects in the Gape Verde Islands, the Dominican Republic and Western Samoa. The integrated pest control project of the Gape Verde Islands is presented at this conference in the detailed report of the General Director of Plant Production and Protection of the Ministry for Rural Development (MDR) Praia, Maria-Luisa Lobo-Lima. The other integrated pest control projects follow more or less the same pattern.

Facing the problems of increasing use of pesticides, there are substantial problems in regard to residue monitoring. Because of the expensive and eleborate methods of analysing residues, the GTZ supports a pesticide residue project on a supra-regional level, with the objective to crate residue analysing facilities in developing countries by supplying analytical equipment and giving advice on technical matters.

.../...

One of the main purposes of the agency is to transfer the knowledge of skilled technical personnel sent from Germany to the local counterparts. Pest problems that arise at national levels are discussed, seminars held and technical papers presented. Moreover, all projects offer scholarships for further education of partners either in place, in Germany or other countries.

Furthermore GTZ prepared a plant protection manual suitable for worldwide use : "Diseases, Pests and Weeds in Tropical Crops"; ed. by J.KRANZ ; H. SCHMUTTERER & W.KOCH ; Hamburg 1977. A French and Spanish version are in press. The German version was edited in 1979. This book was initiated on a recommendation of German extension workers. The authors are professors at the universities Giessen and Hohenheim.

Finally the editorial staff of the agency issues a series of publications (GTZ-Schriftenreihe). It provides the projects-and anybody who requests with general and specific information of different subjects. One item of major interest is plant and post harvest protection. This series which covers over one hundred titles is to be continued.

The GTZ also supports research programs. It is understood that by undertaking a project in the field of plant production a tremendous amount of investigation has to be done. It is not only necessary to identify the major part of the pest organisms but also to analyse the feasibility of their control. Besides these more general research activities, there are projects centered on the problem of one particular pest organism, e.g. the coffee rust control (H.vastatrix) in Columbia. This research project works on factors causing resistance in coffee plants, helps to establish an early warning system with forecasting methods and quarantine measures.

Under this aspect is also included the supra-regional project of natural active insecticide substances. Pyrethrum produced from Chrysanthemum cinerariaefolium is well known as a natural insecticide with a high knock down activity and low mammalian toxicity. To discover other plant-borne substances and to demonstrate their possibilities in pest control, the research work this project was initiated.

.../...

The selection, extraction and screening of the plant-inherent substances, their analysis and mode of action (repellent, antifeedant, insecticidal properties) are described. Propagation on a large scale takes place in Togo. There the preparation of seed and leaf extracts of one of the most promising substances of the Neem tree (Azadirachta indica) is taught and its different possibilities in pest control measurements tested. Other plant extracts are in preparation. The use of these substances permits a greater autonomy in the supply of insecticides by practically eliminating the problems of residues.

Post harvest losses are estimated to be 20-30 %. Even though a regulation of the population density of pest organisms by parasites and diseases in the fiel would be the ideal form of pest management, in stored food protection the possibilities of biological control are very limited. The release of predators and parasites in storage facilities is scarcely justifiable. The total number of insects would be raised, though not by the pest species. Beneficial insects also produce metabolic products, exuvia and dead bodies. These circumstances minimize, despite the possible beneficial aspects, from the medical, hygienical and psychological point of view the use of biological control measures in stored food products.

The best means to lower losses in storage is to provide good plant protection. Therefore the GTZ-post harvest protection projects on national levels are normally linkeel to plant protection in countries like the Cape Verde Islands, Niger, Philippines, Tonga and Western Samoa. On the other hand the agency employs also a supra-regional stored product project. It works on requirements of corresponding counterpart organizations. The aim is to reduce the losses especially at the farmers'levels thus raising the food availability for farmers and their incomes.

INTERNATIONAL CONFERENCE ON BIOLOGICAL CONTROL OF PESTS, ITS POTENTIAL IN WEST AFRICA

THE INTERNATIONAL ORGANIZATION OF BIOLOGICAL CONTROL (I.O.B.C.)

1 Definition and Structure

2 Objectives

3 Formation of the Africa Regional Section

4 Procedures and Membership Costs of IOBC

By Abel Lebrun MBIELE
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B.P. 4170 Nlogkaka
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THE INTERNATIONAL ORGANIZATION OF BIOLOGICAL CONTROL (IOBC)*

1 - Definition and Structure

2 - Objectives

3 - Formation of the Africa Regional Section

4 - Procedures and Membership costs of the IOBC

I. Definition and Headquarters of the IOBC

1) The IOBC is an organization of biologists whose research, in the areas of agriculture, forestry and public health, is specific to the introduction of beneficial insects and patogens, as an economical method of pest population control.

2) Biological control uses living organisms to reduce insect pest loss or damage on vegetation and vegetable products in both forestry and agriculture. It is also used to prevent or reduce the harmful effects of insects or other pests upon man's health.

3) The IOBC headquarters is in Switzerland and, through international agreement, the office of Secretary General is located in Paris, France.

*Organisation Internationale de Lutte Biologique (OILB)

II. Functions and Objectives

The organization's role consists of promoting.

1) Promoting:
   - a) The development of biological control and its integration into antiparasitic control programs;
   - b) International cooperation in the area of biological control;

2) Initiating at National or International Levels:
   - a) Research
   - b) Training of personnel
   - c) Raising public consciousness of biological control and its socio-economic importance.

3) Coordinating and Encouraging the large scale application of biological control

4) Collecting, evaluating and disseminating biological control information.

5) Sponsoring conferences, workshops, and symposiums on topics related to biocontrol.

6) Taking any actions necessary to the attainment of the organization's general goals;

7) Finally, consulting, collaborating or signing agreements with national, international or governmental organizations, keeping in view the above objectives.

III. Internal Structure of the IOBC

The IOBC consists of:

A) The General Assembly

The assembly is open to all members and meets approximately every four years, prefereably in conjunction with international congresses. Special sessions can be held at the request of at least one-fifth of the membership or upon a decision of the council.

Elected officials are the President, Vice-President, and Treasurer (ineligible to serve consecutive terms) and the Secretary General (who can serve consecutive terms).

The General Assembly decides upon any changes in IOBC statutes, furnishes information on the organization's activities, and gives members a chance to express their opinions of those activities and make recommendations to the Council.

B) The Council

The Council is composed of Executive Committee members and of one representative from each of the regional sections. It meets, as necessary, once every two years. It may invite any expert to participate as a consultant at these meetings.

The Council is responsible for the functioning and organization of the following areas:

- promoting international cooperation
- advising and disseminating information on integrated pest management.
- promoting and approving the creation of regional sections and coordinating inter-regional activities.

- finalizing cooperative programs with other international organizations.
- reporting on progress and annual program activities to members and to the general assembly.
- preparing the budget
- preparing the agenda for meetings of the General Assembly;
- sending out ballots by mail.

The Council offers services of general interest to members including documentation, information, and publication. Other areas could also be explored to promote the organization's objectives.

Internal rules are made and, if necessary, changed by the Council. Decision-making is by majority vote, the President casting the deciding ballot in case of a tie. Procedural rules are adopted therein and persons are designated to sign for the organization.

C) The Executive Committee

The Executive Committee is composed of the President in power, the out-going President, the Vice-President, and the Secretary General.

It can appoint a member to fill a post vacated between elections for the remainder of the term.

The Executive Committee is responsible for carrying out the Council's decisions and meets whenever necessary. It reports its activites to the Council, to which it submits emergency measures for approval when necessary.

D) The Regional Sections

The IOBC is structured so that of the four regional sections operate autonomously:

N^o	REGIONAL SECTION	ZONE COVERED
1	West Palearctic	Western Europe, North Africa and the Middle East
2	Western Hemisphere	North and South America
3	South-East Asia	South and East Asia
4	East Palearctic	All COMECOM countries

The sections are autonomous in structure, financing and activities, providing that these procedures are compatible with the organizational statutes and the general Council Policy.

The regional sections' statutes and internal regulations and their modifications are submitted to the Council for approval.

Each regional section designates a representative to serve on the Council.

The section pays for the costs incurred and for his proxy's participation in the Council meetings.

There are projects to create autonomous regional sections in:

1. The Austral-Pacific zone; and
2. Africa

IV. The Regional Section and the IOBC in Africa

The creation of an IOBC section is dependent upon a request submitted by three institutional members representing at least more than one country of the region concerned. The sections are broken down as far as possible into biogeographic zones, even though at times the community interest, scientific resources, economics, and other aspects are in a position to influence decisions relative to their number and dimensions.

As for the creation of the African regional section, the OAU scientific secretary already has received applications for membership from a number of African biologists through their respective government channels. The following countries are involved:

- Central African Republic
- Sierra Leone
- Djibouti

Several member governments have given their approval, even though final acceptance has not yet been granted.

Numerous cases of biological control of food crop pests, using their natural ennemies have been reported by OAU member countries. Some of these cases are cited below:

1) Dr. Yeboa (A. Yeboa 1979) identified the destruction of the following plant fiber pests in his research in Ghana:

a1) Evidence of Spodoptera Litteralis Boisd. Larvae destruction. (Noctuidae). Okra leaf, bud and flower infestation by Peribaea Orbata W. (tachinide) in Kwadaso (Ghana).

a2) Xanthodes Graellsi Freisth (noctuidae) by Sisyrona Stylata (tachinide);

a3) Dysdercus Superstitiosus (Fabr.) by Phonoctonus Fasciatus P.B. and P Sribimpictus Stal (Hemipterous reduviidae).

2) In his research document Phytophagous Insect Gathering on Fruit Trees in Nigeria, Dr. S.O. Boboye (1974) noted parasitism of Coccophagus Princeps Silv. and Coccophagus sp. on Coccus Hisperidum infesting fruit trees.

The above examples are among many others cited by African researchers in the course of their limited research efforts to date.

Honorable colleagues, no participant should ignore technical economic and social importance of well-managed biological control. Chemical control pollutes the environment with large quantities of phytotoxic residues as well as residues toxic to handlers and consumers of the treated plants. Biological control, on the other hand, only introduces beneficial insects to the environment which both we and the farmers appreciate.

The creation of the IOBC Africa Section will allow the African continent in general and the member states in particular, to benefit from an entire scientific research program at national, sub regional, regional or multi-regional levels. This program will be coordinated and will follow up on biological control topics in Agriculture, Forestry and Public Health.

Direct IOBC internvention will alleviate the technical and financial duties of our biological researchers. It will also contribute (on a mid or long term basis) to an appreciable reduction of financial outlays by African farmers who now use chemicals to destroy potential crop pests. Indirectly, IOBC intervention will reduce most farmer's inertia and passive acceptance of catastrophic economic loss due to the devestation of their crops by parasites which are technically controllable.

On a technical scale, the IOBC will serve as the fundamental technical base for crop protection biologists. This base will provide coordination and technical cooperation for all national programs dealing with biological control in Agriculture, Forestry and other related fields.

Once established, an African section will contribute to the growth of coordinated research projects in order to deal (at national, regional and multi-regional levels) with insect pest problems. The section will assume responsibility for the rational execution of such programs.

To this end, I am attaching a recapitulation of several research projects on biological control of crop pests. These OEPP approved projects have been organized, coordonated and carried out in the United Kingdom by an IOBC section.

Why couldn't the African continent benefit from similar efforts by the IOBC and the Interafrican Phytosanitary Council? It would gather and disseminate scientific information on biological control in Africa and elsewhere, in accordance with the organization's objectives.

Honorable biologists, the strengthening of our research activities will, for the most part, lead to integrated control and rational technical and economical solution to many inherent crop protection problems. These are notably:

a- insect pest tolerance

b- environmental pollution from toxic and phytotoxic residues.

c- economics of internvention

d- setting up and reinforcing technical cooperation in pest management on a sub-regional, multiregional and international level.

These are the technical and financial advantages which would favor the stablishment of an IOBC African Section.

Membership and Financial Obligations

Please see the document submitted from Paris by the IOBC Secretary General.

THE COMMONWEALTH INSTITUTE OF BIOLOGICAL CONTROL - CAB'S BIOLOGICAL CONTROL SERVICE TO WORLD AGRICULTURE

by

Fred D Bennett
Director
COMMONWEALTH INSTITUTE OF BIOLOGICAL CONTROL
GORDON STREET, CUREPE
REPUBLIC OF TRINIDAD & TOBAGO

The Commonwealth Institute of Biological Control - CAB's Biological Control Service to World Agriculture[1]

by

Fred D. Bennett[2]

The Commonwealth Institute of Biological Control (CIBC) set up as a branch of the Commonwealth Institute of Entomology in 1927 provides a world service in applied biological control. CIBC operates a network of Stations and its services can be contracted by any country. It is prepared to establish a unit or to undertake investigations in most areas of the world should adequate incentive and funding be available.

To place CIBC in proper context, it is necessary to outline briefly the activities of its parent organization the Commonwealth Agricultural Bureaux (CAB). Founded in 1929, CAB consists of a Headquarters, four Institutes and ten bureaux. This organization is controlled by an Executive Council comprising representatives of 26 member countries which provide basic financial support, and employs approximately 185 scientists and 200 supporting staff. CAB serves agricultural science by providing an Information Service, an Identification Service and a Biological Control Service.

CAB Information Service

CAB acts as a clearing house for the collection, collation and dissemination of value to agriculturalists worldwide. This world coverage is published in 42 abstract journals, 40,000 copies

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[1] Invitational address presented at the USAID Regional Food Protection Conference "Biological Control of Pests: Its Potential in West Africa". Dakar, Senegal, February 9-13, 1981.

[2] Director, Commonwealth Institute of Biological Control, Gordon Street, Curepe, Republic of Trinidad & Tobago, West Indies

of which are sold annually in 150 countries.

Since 1973 the journals have been produced by computer assisted processes. The number of entries, i.e., abstracts of scientific papers, is increasing by more than 150,000 per annum and the CAB data base already contains over one million entries.

The CAB Abstracts Data Base is available through various hosts including Lockheed's Dialogue, SDC Orbit, European Space Agency's IRS and DIMDI. Detailed information on this as well as on other aspects of CAB services is available from CAB Headquarters, Farnham House, Farnham Royal, Slough, UK.

On-line searching is a highly cost-effective way of carrying out literature searches. Relevant literature can be found quickly and print outs obtained thereby saving hours of manual effort. The cost of searching CAB's Data Base is less than £35 per hour for computer time with additional charges for telecommunications and printing. Most searches cost less than £30. Copies of over 3,000 retrospective searches already performed are available at low cost. CAB can also provide copies of most original documents abstracted for the Data Base. Magnetic tapes are available for those wishing to search CAB sbstracts on their own computer.

CAB Identification Services

Accurate identification of a pest or plant pathogen is vital to planning a control strategy. The identification of insects and mites, of microfungi and bacteria, of helminths of animals and man and of entomophilic and plant parasitic nematodes are covered by the Commonwealth Institute of Entomology (CIE), Mycology (CMI) and Helminthology (CIH). These Institutes offer efficient and reliable indentification service to agricultural and biological scientists throughout the world. The service is provided free to CAB member countries whereas others, including commercial organizations within member countries, are normally asked to pay a fee. Developing countries where there is an FAO regional representative can apply for financial assistance from FAO.

In addition to providing identifications, these Institutes also provide other services including the preparation of abstracting and research publications, taxonomic training courses, information retrieval, distribution maps of pests and diseases and consultancy services

CAB Biological Control Service

The Commonwealth Institute of Biological Control operates a series of Stations in several parts of the world and offers an international service for controlling pests of plants, animals or man by the manipulation of their natural enemies. These services include the evaluation of pest and weed situations, advice on the value of biocontrol agents, cooperation in large-scale biocontrol and pest management projects, the exploration for and the supply of biotic agents, the dissemination of information on biological control and training in biocontrol methods. At present CIBC, which is the only CAB Institute with its Headquarters outside the UK, operates main regional bases in Trinidad (where its Headquarters is located), India, Pakistan and Switzerland and allied units in Ghana, Malaysia and Mexico. Negotiations to open a regional unit in Kenya to become operative in April 1981 were completed in January 1981. CIBC also operates an Information Service in the United Kingdom and plans are in progress to expand this to include a research and development unit.

While the major activity of CIBC has been the implementation of biological control particularly classical biological control, it fulfills several functions.

a) Disseminating information on biological control: An important and on-going contribution by CIBC is the preparation of Catalogues of the natural enemies of arthropod pests. Two series of Catalogues the first comprised of natural enemy records covering the period 1913-1937 and the second for 1938-1962 have been completed. Card files are being prepared for a third which will be based eventually on a computerized data bank.

CIBC also publishes regional reviews of biological control: those on Australia, Canada, the Ethiopian Region, SE Asia and the Pacific and Western and Southern Europe are published. Reviews on the Caribbean and Eastern Europe are under preparation and Canada has agreed to prepare one on recent biocontrol activities within Canada.

In 1980 CIBC commenced publication of a new abstract journal Biocontrol News and Information (BNI) issued quarterly. In addition to abstracts it contains short items on current biological control programmes, notice of forthcoming meetings, book reviews, conference reports and a review article. The Institute also prepares Status Papers which summarize previous knowledge on important groups of pests or weeds and consider strategies to be adopted.

b) Training: CIBC has offered bench-type training at its main Stations for many years. Trainees spend periods ranging from a few days to several weeks working alongside CIBC technicians to gain practical experience in rearing natural enemies and their hosts and to participate in release and evaluation programmes. Also, CIBC staff members who have an affiliation with neighbouring Universities co-supervise MSc and PhD students who undertake their research at CIBC. In 1980 CIBC held its first International Training Course at its Indian Station where 18 students from 13 countries participated in the four-week course. A similar course to be held in Trinidad is projected for mid-1982.

c) Implementing biological control: The chief function of CIBC traditionally has been as a supplier of biotic agents. This activity ranges from original projects where little or no previous research has been carried out and where two or more years of developmental studies may be required before any organisms are introduced to "mail order" requests for the supply of natural enemies which have been utilized elsewhere and can be obtained readily and cheaply. CIBC maintains close links with organizations such as FAO, WHO, ODA, GTZ, USDA, CIDA, IDRC etc., undertakes consultancies on their behalf and contracts for research or applied biological control.

Its activities are not strictly limited to biological control of pests and weeds. CIBC is currently undertaking investigations in oil palm pollination in Malaysia and Cameroun. These have demonstrated the role of a group of weevils *Elaeidobius* spp. which are the main pollinators of oil palm in West Africa. The first species *E. kamerunicus* has been introduced into Malaysia and Papua New Guinea where experimental releases of these highly host specific insects which breed in the spent male inflorescence of the oil palm were made in early 1981.

Achievements of CIBC in biological control

Investigations in which CIBC has played either a major or minor role have led to some outstanding successes in many parts of the world (CIBC 1980). Certain of these are included because of their relevance to the Sahel area and to demonstrate that biological control can be achieved over a broad range of climates and against pests on a wide variety of crops.

Tropical fruits

Classical biological control claimed its first major success when the cottony cushion scale *Icerya purchasi* was brought under control by the importation of the Australian coccinellid *Rodolia cardinalis*. This insect has also provided an excellent example of the "mail order" type of service wherein proven natural enemies can be supplied readily to other countries. Since 1880 when success was apparent in California *R. cardinalis* has been distributed to over 35 countries. CIBC has participated on several occasions.

In Peru the rufous scale, or West Indian red scale *Selenaspidus articulatus* was considered to be one of the key pests of citrus, i.e., a pest which had to be controlled by pesticide applications which in turn set up the balance between other pests and their natural enemies. Following preliminary investigations in the West Indies which led to the conclusion that the scale was of African origin CIBC supplied the parasite *Aphytis roseni* from Kenya. This led to satisfactory control and also provided an essential component for the integrated control of citrus pests in Peru.

CIBC has also assisted in the introduction of parasites of the citrus blackfly *Aleurocanthus woglumi* to several countries in Africa and the Caribbean following their successful introduction into Mexico as a result of joint USA-Mexican endeavours. The banana skipper *Erinota thrax* a SE Asian leaf roller following its appearance in Mauritius was brought under control by the egg parasite *Ooencyrtus erinotae* and the larval parasite *Apanteles erinotae*.

Plantation crops

In addition to CIBC's role in the introduction of oil palm pollinators from West Africa to Malaysia it has assisted in the development of a successful pest management programme for oil palm pest in Malaysia.

The coconut scale *Aspidiotus destructor* brought under control in Fiji many years ago by the introduction of coccinellids from Trinidad yielded to the same natural enemies when introduced by CIBC in Principe (Simmonds 1960).

Forest pests and shade trees

In Canada larch sawfly was brought under substantial control between 1910 and 1913 by the introduction of the European parasite *Mesoleius tenthredinus*. Outbreaks occurring in the 1940s were attributed to the development of a host strain capable of encapsulating the parasite larvae. Investigations in Europe led to the introduction of a Bavarian strain of the same parasite in 1961 which was less susceptible to encapsulation and provided control. Another major success in Canada followed the introduction of two parasites *Cyzenis albicans* and *Agropyron flavevlatus* from Europe to control the European winter moth.

Biological control projects against tropical forest pests include the pine mite *Oligonychus milleri*, a pest of *Pinus caribbaea* in Jamaica, the mahogany shoot borer *Hypsipyla grandella* in the Caribbean and *Pineus pini* in Kenya and Hawaii.

Pests of graminaceous crops

In the West Indies some of the earliest successes in biological control were achieved by the introduction of tachinid parasites for the control of the sugarcane borer *Diatraea saccharalis*. Investigations have continued and a major success was achieved in Barbados where following the establishment of the tachinid *Lixophaga diatraeae* and the Asian braconid *Apanteles flavipes*, in the mid-1960s. By 1970 the parasites had reduced damage from 16% to less than 6% and have since maintained satisfactory control without the need for further releases. CIBC has shipped *A. flavipes* to Brazil where several millions are released each year to control sugarcane borers.

In Tanzania and Mauritius the white sugarcane scale *Aulacaspis tegalensis* has been brought under control by parasites and predators supplied by CIBC.

Weeds

CIBC has undertaken investigations which have led to spectacular control of several weeds including *Opuntia tricantha* in Nevis, *Eriocereus martinii* in Queensland, Australia, *Cordia curassavica* in Mauritius, Sri Lanka and Peninsular Malaysia.

Of particular relevance to West Africa are the investigations on natural enemies of *Chromolaena odorata*. At its West Indian Station, several natural enemies have been studied. Similarly, CIBC has introduced or supplied natural enemies of *Lantana camara* to several African and Asian countries. CIBC has studied the natural enemies of the parasitic weeds *Striga* spp. and once the natural enemies have been studied in the Sahel area, could supply cultures of the more promising species.

The Institute has also been active in biological control of the aquatic weeds, particularly water fern *Salvinia molesta* and water hyacinth *Eichhornia crassipes*, and has carried out preliminary investigations on water lettuce *Pistia stratiotes*.

Potential role for CIBC in West Africa

In the Sahel area there have been relatively few attempts to obtain biological control of pest species by the introduction of exotic natural enemies. With the harsh environment prevailing in the Sahel, it may be difficult to obtain parasites and predators that adapt readily to the region. On the other hand, where studies have been conducted in the Sahel, natural enemies have been shown to exist. Hence, it is probable that the introduction of other species from areas with similar climate, could compliment the action of native species and thereby alleviate certain pest problems. It has been demonstrated thatthe white date palm scale *Parlatoria blanchardi* can be controlled by the introduced *Chilocorus bipustulalis* although periodic releases may be required.

There are many pests and certain weeds in this area for which biological control investigations have been undertaken elsewhere. CIBC has experience and can provide expertise for several of these which are chronic and urgent problems in the region.

1. The cassava mealybug *Phenacoccus manihoti*: A neotropical species which is spreading rapidly in West Africa, causes serious damage and even crop failure. Under a grant from IDRC, entomologists at the West Indian Station are

searching for natural enemies which will be supplied to the region through IITA or direct to interested parties.

2. The Neotropical cassava green mite *Mononychellus manihoti*: Introduced into East Africa on cassava cuttings, the mite has spread rapidly across Africa. CIBC has investigated its natural enemies in the Neotropics and can supply cultures to countries in West Africa when the mite becomes a problem.

3. Graminaceous stem borers: CIBC has undertaken investigations on the natural enemies of stem borers in East Africa, West Africa, India, Pakistan and the neotropics. It has tested the host suitability of several parasites from Asia on Neotropical stem borers and vice versa and can supply cultures of natural enemies from these regions for trial in West Africa and can offer advice and assistance in setting up parasite breeding and monitoring programmes.

4. Sorghum midge *Contarinia sorghicola*: This is a cosmopolitan pest of sorghum. Natural enemies are known to be present in many areas of the world but there is need for the establishment of a global programme to facilitate the regional exchange of natural enemies. CIBC with its network of Stations is well placed to undertake this.

5. *Chromolaena odorata*: A neotropical composit weed also known as *Eupatorium odoratum* was accidentally introduced into West Africa many years ago and continues to spread unchecked. CIBC has investigated and undertaken safety tests with certain of its natural enemies and recommended trials with two species *Pareuchetes pseudoinsulata* (referred to in earlier literature as *Ammalo insulata*), an arctiid defoliator and *Apion brunneonigrum*, a seed weevil.

6. *Striga* spp. Witchweeds: These weeds, parasitic on the roots of other plants particularly Graminae, are serious

pests in West Africa. CIBC has undertaken surveys of natural enemies in India and East Africa (Girling et al. 1980) and can supply experienced staff to assess the situation in West Africa and ascertain whether the introduction of additional natural enemies is warranted.

7. Aquatic weeds: Aquatic weed problems already exist in some water impoundments in West Africa, e.g., *Eichhornia crassipes* in Senegal, Nigeria, Congo and Zaire and *Pistia stratiotes* in most countries of West Africa. CIBC has studied the natural enemies of these and also of the aquatic fern ***Salvinia molesta*** and can provide expertise and can supply natural enemies.

In summary with its network of Stations and personnel, with worldwide experience in biological control CIBC can assist in several ways. It can provide short-term consultants to advise in setting up biological control programmes and the design and staffing of biological control facilities within the region. It can provide bench-type training for technicians and scientists at its various Stations; it is prepared to organize and to run special courses in biological control. Through its Information Service it can provide background information on pests and weeds and their natural enemies. Finally CIBC is prepared to contract to undertake investigations in the region and/or to supply cultures of natural enemies.

RELEVENT LITERATURE

Andres, L.A. & Bennett, F.D. (1975) Biological control of aquatic weeds. Ann. Rev. Entomol. 20: 31-46.

Bennett, F.D. (1965) Tests with parasites of Asian graminaceous moth borers on Diatraea and allied genera in Trinidad. Commonw. Inst. biol. Control Tech. Bull. 5: 101-116.

____________ (1975) Insects and plant pathogens for the control of Salvinia and Pistia. Proc. Symp. on Water Quality Management through Biological Control, University of Florida 28-35.

____________ (1977) Insects as agents for biological control of aquatic weeds. Aquatic Botany 3: 165-174.

____________ & Cruttwell, R.E. (1973) Insects attacking Eupatorium odoratum in the Neotropics. 1. Ammalo insulata (Walk.) (Lep.: Arctiidae) a potential biotic agent for the control of Eupatorium odoratum L. (Compositae). Commonw. Inst. biol. Control Tech. Bull. 16: 105-115.

____________ & Greathead, D.J. (1978) Biological control of the mealybug Phenacoccus manihoti Matile-Ferrero: prospects and necessity. Proc. Cassava Prot. Workshop, CIAT, Colombia 7-12 Nov. 1977: 181-194.

Commonwealth Agricultural Bureaux (1980) Biological Control Service - 25 Years of Achievement. CAB 24 pp.

Commonwealth Institute of Biological Control (1978) Screening Organisms for Biological Control of Weeds. Comm. Agr. Bureaux 6pp.

Cruttwell, R.E. (1973) Insects attacking Eupatorium odoratum in the Neotropics. 2. Studies on the seed weevil Apion brunneonigrum BB and its potential use to control Eupatorium odoratum L. Commonw. Inst. biol. Control Tech. Bull. 16: 117-124.

Girling, D.J. (1979) Parasierola sp. (Hym.: Bethylidae) a parasite of Eldana saccharina Wlk. (Lep.: Pyralidae). Entom. mon. Mag. 113: 211-212.

Girling, D.J., Bennett, F.D. & Yaseen, M. (1978) Biological control of the green cassava mite Mononychellus tanajoa (Bondar) (Acarina: Tetranychidae) in Africa. Proc. Cassava Prot. Workshop, CIAT, Colombia 7-12 Nov. 1977: 165-170.

_____________, Greathead, D.J., Mohyuddin, A.I. & Sankaran, T. (1979). The potential for biological control in the suppression of parasitic weeds. Biocontrol News and Information Sample Issue. pp. 7-16.

Greathead, D.J. et. al (1971) A Review of Biological Control in the Ethiopian Region. Commonw. Inst. biol. Control Tech. Comm. 5, 162 pp.

Rao, V.P., Ghani, M.A., Sankaran, T. & Mathur, K. (1971) A Review of the Biological Control of Insects and Other Pests in South-East Asia and the Pacific Region. Commonw. Inst. biol. Control Tech Comm. 6, 149 pp.

Simmonds, F.J. (1960) Biological control of the coconut scale Aspidiotus destructor Sign. in Principe P.W.A. Bull. ent. Res. 51: 223-237.

_____________ & Bennett, F.D. (1977) Biological control of agricultural pests. Proc. XV Int. Congr. Ent. 464-472.

BIOLOGICAL CONTROL OF INSECT PESTS OF SORGHUM AND PEARL MILLET IN WEST AFRICA[*]

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Abstract

Present situation of insect pests of sorghum and pearl millet in West Africa is summarized. Notes on distribution and host range of parasites, predators and pathogens are presented and the scope of biological control is discussed. Among parasites reported from West Africa : Apanteles sesamiae Cam., Tetrastichus atriclavus Wts., Pediobius furvus Gah., Hyperchalcidia soudanensis Stef., Sturmiopsis parasitica Curr. are major parasites of stem-borers and Tetrastichus diplosidis Crawf. and Eupelmus popa Gir. are of grain midges. Ants, coccinellids, syrphids and bugs may prove useful as potential predators. Surveys and further studies on insect pests and natural enemies are suggested.

I - Introduction

In West Africa, sorghum (Sorghum bicolor (L.) Moench) and pearl millet (Pennisetum typhoides Stapf. & Hubb.) are the major food crops occupying an area of about 17 million hectares. These crops are damaged by a range of insect pests. Efforts have been made to evolve suitable control strategies in order to reduce the pest populations and thus the crop losses; viz. stem-borers (Harris, 1962); grain midges (Harris, 1961; Coutin, 1970 a,b); millet earhead caterpillars (Vercambre, 1978) and shootfly (Adesiyun, 1978).

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At present, few cultural practices (partial burning of stems, dates of planting etc.) are being evaluated for the control of stemborers. Similarly, work on varietal resistance to the pests of sorghum and pearl millet is underway through ICRISAT's regional programme. It is proposed that the surveys and biological and ecological studies on insect pests and their natural enemies should be undertaken. This would help in future to plan an integrated control where all suitable technique could be used in a compatible manner to maintain the pest populations below economic injury levels.

The objective of the present paper is to review the biocontrol research in West Africa and to discuss its scope in controlling the major insect pests of sorghum and millets.

II - Major pest species on sorghum and millets

The insect pests attacking sorghum and millets have been surveyed by Risbec (1950) and Appert (1957) in Senegal and Mali; Forsyth (1960) in Ghana; Ajayi (1978) in Nigeria; Bridge et al. (1978) in the Gambia; Ndoye (1979 a) and Gahukar (1981 a) in Senegal; Bonzi (1980) in Upper Volta and Doumbia (1980) in Mali. Only the pests of economic importance are discussed here.

(i) Seedling pests : Leaf feeding beetles and shootflies (Chloropidae, Muscidae) attack these crops at seedling stage. Of the shootflies identified in West Africa, only *Atherigona soccata* Rond. is a major pest attacking sorghum, specially the late planted crops (Deeming, 1971; Adesiyun, 1978; Gahukar 1981 b).

(ii) Foliage pests : Young as well as old leaves are eaten, throughout plant growth, by a number of lepidopterous pests. Some are sporadic pests and complete defoliation may occur in case of early attack; viz. *Spodoptera exempta* Wlk., *S. exigua* Hb., *Mythimna loreyi* Dup., *M. separata* Wlk., *Amsacta moloneyi* Drc. During the prolonged droughts, aphids (*Rhopalosiphum maïdis* Fit.) invade young plants of sorghum and cause some reduction in yield.

(iii) *Stemborers* : The following stemborers have been recorded on graminaceous crops; some of them are important pests (Risbec, 1950, 1960; Harris, 1962; Brenière, 1971; Bonzi, 1977; Ndoye, 1977; Doumbia, 1980).

Busseola fusca Fuller
Sesamia calamistis Hmps.
S. penniseti Tams and Bowd.
S. poephaga Tams and Bowd.
S. cretica Led.
S. nonagrioides botenphaga Tams and Bowd.
Manga basilinea Bowd.
Acigona ignefusalis Hmps.
Eldana saccharina Wlk.

A description of life history of major borers and host plants has been given by Harris (1962). *B. fusca* is a major pest of sorghum and maize in most parts of tropical Africa. Whereas, *S. calamistis* is a polyphagous pest distributed throughout East and West Africa. Another important borer, *A. ignefusalis* prefers millet but also attacks sorghum and other cereals in West Africa.

(iv) *Earhead pests* : The sorghum midge (*Contarinia sorghicola* Coq.) and millet midge (*Geromyia penniseti* Felt.) attack flowering heads and can cause up to 100% yield loss. Biology of these pests has been studied in Senegal and Nigeria (Harris, 1961; Coutin and Harris, 1968; Coutin, 1970 a). Since 1972, a complex of species including *Masalia* spp., *Raghuva albipunctella* De Joannis; *Raghuva* spp., has been noticed attacking millet (Vercambre, 1978). Recent studies in Senegal confirmed that only *R. albipunctella* is a major pest in sahelian countries (Ndoye, 1979 b). The developing grains are devoured by *Heliothis armigera* Hbn., *Eublemma gayneri* Roths. and *Pyroderces simplex* Wsm. which sometimes may cause some losses.

Various species of bugs, blister beetles, thrips, jassids, earwigs, grasshoppers attack the crops during vegetative and flowering stages. Detail studies are necessary on these insects to assess the yield loss and economic injury levels.

III - Parasites, predators and pathogens on major pests

(i) Parasites : A range of hymenopterous and dipterous parasites have been reported from West Africa (Table 1). The families of these parasites are as follows :

Hymenoptera : Braconidae
Bethylidae
Chalcidae
Encyrtidae
Eulophidae
Eupelmidae
Eurytomidae
Ichneumonidae
Platygasteridae
Pteromalidae
Scelionidae

Diptera : Sarcophagidae
Tachinidae
Chloropidae
Phoridae

The review of literature indicates that very little information is available on the estimation of efficacy of these parasites in the control of insect pests in West Africa. In Nigeria, Harris (1962) reported that 3 parasites (*Apanteles sesamiae* Cam., *Tetrastichus atriclavus* Wts., *Pediobius furvus* Gah.) were effective in controlling the larval population of *B. fusca* while *Syzeuctus* sp. was effective against *A. ignefusalis*; even though the level of parasitism was only 10%. Furthermore, their population varied from year to year and from one species to another.

Recently, Ndoye (1980) studied the biology of a bethylid, Goniozus procerae Risb. which attacked less than 2% of the diapausing larvae of A. ignefusalis in Senegal.

Coutin and Harris (1968) observed considerable reduction in millet midge populations due to parasites. On sorghum midge, Eupelmus popa Gin. was predominent in Senegal and Nigeria (Harris, 1961; Coutin, 1970 a). Our observations during the last 3 years show that Tetrastichus spp. and Eupelmus spp. are important in controlling sorghum midge, but parasitism is usually low during the peak of pest incidence. Their populations increase only at the end of crop season when the pest incidence is decreasing and crop is already damaged. Moreover, favourable climatic conditions and availability of flowering heads play an important role in the fluctuations of parasite populations.

In case of dipterous parasites, they are comparatively rare in West Africa. One potential parasite is a tachinid, Sturmiopsis parasitica Curr. which attacks stemborers. The role of sarcophagids, chloropids and phorids as parasites is problematical since they are saprophagous.

(ii) Predators : Predators like ants, beetles, bugs, syrphids and mites attacking stemborers, grain midges, aphids and Amsacta larvae have been reported from West Africa (Table 2). Among vertebrates, birds are obviously important as insect predators; although their effectiveness has not been studied yet. Similarly, behaviour of spiders and chrysopids should be studied and perhaps their potentiality can be measured.

(iii) Pathogens : The most common diseases of insects are caused by bacteria, fungi, viruses, protozoa and nematodes. Bacteria and fungi have been identified from larvae/pupae of stemborers in West Africa (Table 3).

IV - Advantages and requirements of biological control

The development of pest management systems should be based on ecological conditions (Huffaker, 1974; Pimentel and Goodman, 1978). Natural enemies play an important role in these systems (Delucchi, 1971; Hurpin, 1975).

In biological control, establishment, multiplication and dispersal on wide area of natural enemies are important steps. Such projects need high initial inputs but can prove to be economical on long term basis; since the control is self perpetuating. Using biological control, risks of environmental pollution, development of resistance by pests to pesticides, toxic effects in food chains, dangerous effects on pollinators and natural enemies etc. are avoided and natural balance is not disturbed. It is true that 100% pest control is not achieved but the pest populations are maintained below economic thresholds. The biological control is successful, particularly in the situations where repeated applications of pesticides are required. Moreover, it can be made more effective by predicting the pest outbreaks.

For successful biological control, correct identification of pest species and their parasites/predators and recognition of cryptic species or intraspecific entities are of utmost importance (Rosen and Debach, 1973). As far as possible, surveys should be made for local parasites since the relationships pests - parasites are stable. These collections may also show distinct races or ecotypes which may be suited to particular host or environment. After having confirmed the absence of local parasites, potential parasites can be introduced if they are (i) pest specific, (ii) non plant breeder, (iii) not attacking other primary parasites. In case of predators and parasites of introduced pests, they are to be searched in the country of pest origin.

V - Possibilities of biocontrol in West Africa

Chemicals were tested against shootflies (Adesiyun, 1978); millet earhead caterpillars (Vercambre, 1978) and grain midges (Coutin, 1970, a, b). However, cost of pesticides, phytotoxicity, application techniques, residues in grains and stalks are some of the problems which require further studies. Cultural practices were suggested for the control of stemborers (Harris, 1962; Adesiyun and Ajayi, 1980); midges (Harris, 1961) and millet earhead caterpillars (Vercambre, 1978); but socio economic problems may hinder the practicability of some of these recommendations. For example, destruction of borer infested stalks which are generally used for hut construction and fencing by villagers. These few examples illustrate the scope for biological control in West Africa.

(a) Transfer of parasites/predators within Africa

There is a urgent need to survey the parasitic fauna and to study their biology, seasonal population fluctuations, potentiality in pest control etc. Then the transfer of selected parasites/predators can be implemented in the same ecological zones within West African countries. In West Africa, parasites suffer in dry season due to climatic conditions and the diapause of host insect. This breaks the synchronisation between host and parasite. Few parasites attack diapausing larvae/pupae, but parasitism is generally at a low level. Thus, there is a scope for introducing few parasites which should be able to undergo a resting stage along with host insects and should be able to multiply quickly and produce a large population when insects become active.

In case of midge parasites, potential parasites exist in West Africa, but they appear late in the season. Suitable conditions should be investigated so that they multiply during high pest incidence. This can probably be done by growing early flowering varieties or alternate host plants as one of the parasites, *T. diplosidis* is strongly attracted to sorghum heads rather than to host insect, *C. sorghicola* (McMillan and Wiseman, 1979).

The major midge parasites are :

(i) Tetrastichus diplosidis Crawf. - It is a larval-pupal endoparasite recorded in Senegal and other West African countries.

(ii) Eupelmus popa Gir. - It is larval-pupal ectoparasite and probably a hyperparasite through T. atriclavus. The first instar larvae feed upon larvae whereas later instars attack pupae. Few larvae, after feeding upon one host, complete their growth upon plant sap.

The following stemborer parasites are important in East Africa (Mohyaddin and Greathead, 1970) and are reported from West Africa; their use can therefore be suggested.

(i) Apanteles sesamiae Cam. - It is a gregarious larval endoparasite, widely distributed in Africa. Even though it is attacked by hyperparasites : Ceraphron sp., Eurytoma sp., Platyerizotes soudanensis Ferr., Pediobius homoeus Wtrst., it is quite successful in wet areas. It produces a large number of adults from a single host.

(ii) Sturmiopsis parasitica Curr. - It is primarily a larval and occasionally a larval-pupal endoparasite. Although few hyerparasites have been reported (Epiencyrtus sp.) from Nigeria, it remains as an efficient parasite due to synchronization of its life history with that of B. fusca.

(iii) Dentichasmias busseolae Hein. - It is a solitary pupal endoparasite, widely distributed in East Africa, and well adapted to dry areas. In West Africa it was found only in Nigeria on A. ignefusalis.

(iv) Pediobius furvus Gah. - It is a gregarious pupal endoparasite, widely distributed in West Africa. It gets adapted to a wide range of ecological conditions and produces many adults from one host insect.

(v) Hyperchalcidia soudanensis Stef. - It is a solitary pupal endoparasite, adapted to drier areas. It has been reported from Nigeria, Senegal, Mali, Kenya, Uganda and Cameroun.

Two West African stemborer parasites, G. procerae, T. atriclavus have been reared in laboratory and were released in African countries (Bordat et al., 1977.

In West Africa, little information is available on egg parasites. Five parasites of family Scelionidae were recovered from lepidopterous pests. Recently, one unidentified species of Trichogramma (Trichogrammatidae) has been reported from Senegal attacking eggs of Raghuva sp. (Bournier J.P. Pers. Commun.). The egg parasites are rare in East Africa; the possibility of their transfer is therefore very less. In Uganda, ants (Tetramorium guineense Fab., Pheidole megacephala Fab., Carciocondyla badonci Arnold and C.emeryi Forel) were found responsible for more than 90% mortality of eggs and early instar larvae of B. fusca and Chilo partellus Swin. (Mohyuddin and Greathead, 1970) and of Eldana saccharina Wlk. (Girling, 1978). However, this may hinder the host availability to egg parasites. Ants also attack larvae and pupae of stemborers harbouring in old stalks; therefore, their potentiality may be explored in borer control.

(b) Introduction of natural enemies

Effective enemies may be imported in West Africa to control either target pest or species related to it or for the same type of micro habitat. These parasites should possess the qualities such as (i) high host searching ability, (ii) high degree of host specificity or preference, (iii) high biotic potential related to host, (iv) good adaptation to wide range of environmental conditions.

Information on a range of parasites of some of the gramineceous stemborers from Asia is available (Bennett, 1965; Sharma et al. 1966; Rao et al. 1971). Mohyuddin and Greathead (1970) discussed the potentiality of some of these parasites and suggested introduction of following parasites in East Africa due to their wide distribution, high biotic potential and wide host range. If satisfactory results are obtained, these parasites can be recommended in West Africa.

(i) *Apanteles flavipes* Cam.
(ii) *A. chilonis* Munak.
(iii) *Bracon chinensis* Szep.
(iv) *B. onukii* Watanabe
(v) *Sturmiopsis inferens* Towns.

Subsequently, first 2 parasites were bred on laboratory host insects and released in Reunion and Madagascar Islands (Bordat *et al.*, 1977).

Other introduced parasites tried in East and West Africa are :

(i) *Tetrastichus israeli* Mani
(ii) *Trichospilus diatraeae* Cher. & Margh
(iii) *Itoplectis narangae* Ashm.

The eulophids, *T. israeli* and *T. diatraeae* may not be effective since they are potential hyperparasites of tachinid parasites (Bennett, 1965).

The effective parasites/predators, particularly *Trichogramma* egg parasites, may be imported from other continents and tried in West Africa. The pathogens whose commercial preparations are available (for example, *Bacillus thuringiensis* Berl), may be used against lepidopterous pests.

Multiplication of parasites for a large scale release may pose a problem in present situations. Importation of parasites needs high cost. Furthermore, development of simple and less expensive breeding techniques and training of staff in handling the parasites may be necessary. The shipments take a long time to reach the place of field release and sometimes the parasites may be found dead. Thus multiple shipments are required for establishment of natural enemy and to study its performance in the given environment. It is suggested that the studies on population ecology and genetics of natural enemies, importation policies and training of personnel should find a place in forthcoming projects on biological control of insect pests.

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References

ADESIYUN, A.A., 1978. Evaluation of some insecticides for the control of sorghum shootfly in Nigeria. Paper presented at the 8th Nigeria Society of Plant Prot., 19pp.

ADESIYUN, A.A. and AJAYI, O. 1980. Control of the sorghum stemborer, Busseola fusca, by partial burning of the stalks. Trop. Pest Manag. 26 : 113-117.

AJAYI, O. 1978. Control of sorghum, millet and wheat field insect pests. Paper presented at second national sorghum, millet and wheat Conference, Zaria, Nigeria; 13pp.

APPERT, J. 1957. Les parasites animaux des plantes cultivées au Sénégal et au Soudan Français. Gouvernement Général de l'Afrique Occidentale Française, Dakar, 292 pp.

BARNES, H.F. 1958. Progress in the biological testing of sorghum midge (Contarinia spp.) Bull. Entomol. Res. 49 : 555-558.

BENNETT, F.D. 1965. Tests with parasites of asian graminaceous moth borers on Diatraea and allied genera in Trinidad. Tech. Bull. Commonw. Inst. Biol. Control N° 5 : 101-116.

BONZI, M. 1977. La situation des foreurs des graminées en Haute-Volta. Présenté à la réunion sur les foreurs des graminées, Bouaké, Côte d'Ivoire, 6pp.

BONZI, M. 1980. Rapport annuel 1979. Défense des cultures, IRAT, Haute-Volta, 50pp.

BORDAT, D., BRENIERE, J. et COQUARD, J. 1977. Foreurs de graminées africaines : parasitisme et technique d'élevage. Agron. Trop. 32 : 391-399.

BRENIERE, J. 1971. Les problèmes des lépidoptères foreurs des graminées en Afrique de l'Ouest. Ann. Zool. Ecol. anim. 3 : 287-296.

BRIDGE, J., TERRY, P.J. and TUNSTALL, J.M. 1978. A survey of crop pests, diseases and weeds of the Gambia. U.K. Ministry of Overseas Development, London. 45pp.

COUTIN, R. 1970 a. Biologie de la cécidomy du sorgho (*Contarinia sorghicola* Coq.) et lutte chimique. *Phyt*. *phytopharm*. 19 : 65 - 83.

COUTIN,,R. 1970 b. Influence de deux insecticides sur la biocénose de *Geromyia* *penniseti* Felt. au Sénégal Commun. VII Congrès Intern. Prot. Plantes, Paris. p. 600-601.

COUTIN, R. and HARRIS, K.M. 1968. The taxonomy, distribution, biology and economic importance of the millet grain midge, *Geromyia penniseti* (Felt.) gen. n. comb. n. (Dipt., Cecidomyiidae). *Bull*. *Entomol*. *Res.* 59 : 259-273.

DEEMING, J.C. 1971. Some species of *Atherigona* Rondani (Diptera, Muscidae) from northern Nigeria, with special reference to those injurious to cereal crops. *Bull*. *Entomol*. *Res*. 61 : 133-190.

DELUCCHI, V. 1971. L'impact des entomophages en protection phytosanitaire. *Meded*. *Facult*. *Landbouw*. *Rijk*. Gent (Belgique) 36 : 831-837.

DOUMBIA, Y.O. 1980. Entomologie du mil et sorgho : Résultats de la campagne 1979. SRCVO, Sotuba; Mali, 68pp.

FORSYTH, J. 1966. Agricultural insects of Ghana, Ghana Academy of Sciences, Accra, 163 pp.

GAHUKAR, R.T. 1980. Rapport annuel du programme d'entomologie du sorgho (année 1979) Multigr. CNRA, Bambey, Sénégal, 77pp.

GAHUKAR, R.T. 1981a. Inventaire des insectes nuisibles du sorgho au Sénégal (en préparation).

GAHUKAR, R.T. 1981 b. Species of Atherigona in West Africa with particular reference to sorghum shootfly (in preparation).

GAHUKAR, R.T. 1981 c. Rapport annuel du programme d'entomologie du sorgho (année 1980) (en préparation).

GIRLING, D.J. 1978. The distribution and biology of Eldana saccharina Walker (Lepidoptera : Pyralidae) and its relationship to other stemborers in Uganda. Bull. Entomol. Res. 68 : 471 - 488.

HARRIS, K.M. 1961. The sorghum midge, Contarinia sorghicola (Coq.) in Nigeria. Bull. Entomol. Res. 52 :129-146.

HARRIS, K.M. 1962. Lepidopterous stemborers of cereals in Nigeria. Bull. Entomol. Res. 53 : 139 - 172.

HUFFAKER, C.B. 1974. Some ecological roots of pest control. Entomophaga 19 : 371-389.

HURPIN, B. 1975. Perspectivité et contraintes de la lutte microbiologique. Z. ang. Entomol. 77 : 377 - 381.

JERATH, M.L. 1968. Parasites of sugarcane stemborers in Nigeria. J. Econ. Entomol. 61 : 435-436.

JORDAN, F.J. 1966. Report on an investigation into the presence and prevalence of rice stemborers and their parasites in Sierra Leone, 1964-1965. West African Rice Res. Stn. Rokupr. 47pp.

McMILLAN, W.W. and WISEMAN, B.R. 1979. Attraction of sorghum midge parasites to sorghum heads. Florida Entomol. 62 : 281-282.

MOHYUDDIN, A.I. and GREATHEAD, D.J. 1970. An annotated list of the parasites of graminaceous stemborers in East Africa, with a discussion on their potential in biological control. Entomophaga 15 : 241 - 274.

NDOYE, M. 1977. Synthèse de quelques résultats sur les insectes foreurs des mils et sorgho au Sénégal, CNRA, Bambey, Multigr. 15pp.

NDOYE, M. 1979 a. L'entomofaune nuisible au mil à chandelle (Pennisetum typhoïdes) au Sénégal. Présenté au Congrès sur la lutte contre les insectes au milieu tropical, Marseille, France, Multigr. 17 pp.

NDOYE, M. 1979 b. New millet spike pests in Senegal and the sahelian zone. Plant Prot. Bull (FAO) 27 : 7-8.

NDOYE, M. 1980. Goniozus procerae Risbec (Hymenoptera, Bethylidae) ectoparasite larvaire d'Acigona ignefusalis (Lepid., Pyralidae, Crambinae), CNRA, Bambey, Multigr., 6pp.

PIMENTEL, D. and GOODMAN, N. 1978. Ecological basis for the management of insect populations. Oikos 30 : 422-437.

RAO, V.P., GHANI, N.A., SANKARAN, T., and MATHUR, R.C. 1971. A review of the biological control of insects and stem pests in South East Asia and the Pacific region. Tech. Bull. Commonw. Inst. Biol. Control N° 6.

RISBEC, J. 1950. La faune entomologique des cultures au Sénégal et au Soudan Français. Gouvernement Général de l'Afrique Occidentale Française, Dakar, 639 pp.

RISBEC, J. 1960; Les parasites des insectes d'importance économique en Afrique Tropicale et à Madagascar. Agron. Trop. 15 : 624 - 656.

ROSEN, D. and DEBACH, P. 1973. Systematics, morphology and biological control. Entomophaga 18 : 215-222.

SHARMA, A.K., SAXENA, J.D. and SUBBA RAO, B.R. 1966. A catalogue of the hymenopterous and dipterous parasites of *Chilo zonellus* Swinhoe (Crambidae : Lepidoptera) Indian J. Entomol. 28 : 510 - 542.

VERCAMBRE, B. 1978. *Raghuva* spp., *Masalia* sp., chenilles des chandelles du mil en zone sahélienne. Agron. Trop. 33 : 62 - 79.

TABLE 1 : Parasites of major insect pests of sorghum and pearl millet reported from West Africa

Order and Family	Species	Host insect and life stage attacked	Distribution	Reference
Order : Hymenoptera				
1. *Braconidae*	*Apanteles sesamiae* Cam.	*B. fusca* (larva)	Nigeria	Harris, 1962
		Sesamia sp. (larva)	Nigeria	Harris, 1962
		S. nonagrioides botenphaga (larva)	Sierra Leone	Jordan, 1966
		A. ignefusalis (larva)	West Africa	Risbec, 1960
	Apanteles syleptae Ferr.	*S. exigua* (larva)	Senegal	Risbec, 1950 Gahukar, 1981
	Apanteles sagax Wikn.	*M. loreyi* (larva	Senegal	Risbec, 1960
	Apanteles ghesquieri Saeg.	*E. gayneri* (larva)	Senegal	Risbec, 1960
	Apanteles aroxys Saeg.	*E. gayneri* (larva)	Senegal	Risbec, 1960
	Apanteles sp.	*S. cretica* (pupa)	Senegal	Risbec, 1960
	Apanteles sp.	*C. sorghicola* (larva/pupa)	Senegal	Gahukar, 1980
	Rhogas mimeuri Ferr.	*H. armigera* (larva)	Mali	Doumbia, 1980
		M. separata (larva)	Mali	Doumbia, 1980
	Euvipio rufa Szepl.	*A. ignefusalis* (larva)	Nigeria	Harris, 1962
	Euvipio fascialis Szepl.	" "	Senegal	Risbec, 1960
	Rhaconotus soudanensis Wilkn.	*A. ignefusalis* (larva)	Senegal	Risbec, 1960
	Rhaconotus sp.	*E. gayneri* (larva)	Senegal	Risbec, 1960
	Habrobracon hebetor Say.	*Raghuva* spp. *Masalia* sp. (larva)	Senegal	Vercambre, 1978
		M. loreyi (larva)	Senegal	Risbec, 1960

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	Glyptomorpha sp.	A. ignefusalis (pupa)	Nigeria	Harris, 1962
	Microdus sp.	M. loreyi (larva)	Senegal	Risbec, 1960
	Phanerotoma sp.	S. cretica (pupa)	Senegal	Risbec, 1960
	Bracon praecepter Brues.	E. gayneri (larva)	Senegal	Risbec, 1960
	Disophrys iridipennis Cam.	S. exigua (larva)	Senegal	Risbec, 1950
	Cardiochiles-sp.	"	Senegal	Risbec, 1950
2. Bethylidae	Goniozus procerae Risb.	A. ignefusalis (larva)	Senegal	Risbec, 1950; Ndoye, 1980
	Goniozus sp.	"	Nigeria	Harris, 1962
3. Chalcididae	Hyperchalcidia soudanensis	A. ignefusalis (pupa)	Nigeria	Harris, 1962
			Senegal	Risbec, 1950
		E. saccharina (pupa)	Mali	Risbec, 1960
	Brachymeria feae Mas.	S. calamistis? (pupa)	Nigeria	Harris, 1962
		M. loreyi (pupa)	Senegal	Risbec, 1950
	Brachymeria eublemmae Stef.	E. gayneri (pupa)	Senegal	Risbec, 1950
	Euchalcidia eublemmae Stef.	"	Senegal	Risbec, 1950
	Paroxycoryphiscus signifer Stef.	E. gayneri (larva)	Mali	Doumbia, 1980
4. Encyrtidae	Paraphaenodisus risbeci Guesq.	S. cretica (pupa)	Senegal	Risbec, 1950
	Euzkadia sp. (? integralis Merc.)	A. ignefusalis (larva)	"	"

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5. Eulophidae	Pediobius furvus Gah.	S. cretica (larva)	Senegal	Risbec, 1950
		A. ignefusalis (pupa)	Nigeria	Jerath, 1966
		S. penniseti ? (pupa)	Sierra Leone	Jordan, 1966
			Ghana	Forsyth, 1966
		B. fusca (pupa)	Nigeria	Harris, 1962
	Pediobius hirtellus Mas.	S. poephaga (pupa)	"	"
	Tetrastichus diplosidis Craw.	C. sorghicola (larva-pupa)	Senegal	Coutin, 1970; Gahukar, 1980
	Tetrastichus atriclavus Wtrst.	B. fusca (pupa)	Nigeria	Harris, 1962
		A. ignefusalis (pupa)	"	"
				Gahukar, 1981a
		Sesamia sp. (pupa)	Nigeria	Harris, 1962
	Tetrastichus celamae Risb.	E. gayneri (pupa)	Senegal	Risbec, 1950
	Tetrastichus spp.	C. sorghicola (larva-pupa)	Nigeria	Harris, 1961
			Ghana	Barnes, 1958
		G. penniseti (larva-pupa)	Senegal	Coutin & Harris, 1963
	Pleurotropis braconivora Risb.	E. gayneri (larva)	Senegal	Risbec, 1950
	Aprostocetus sp.	C. sorghicola (larva-pupa)	Nigeria	Harris, 1961
			Senegal	Coutin, 1970a; Gahukar, 1980
	Euplectrus laphygmae Ferr.	A. moloneyi (larva)	Senegal	Risbec, 1950
		S. exigua (larva)	"	"
		S. exempta (larva)	"	"

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6. *Eupelmidae*	*Eupelmus popa* Gir.	*C. sorghicola* (larva-pupa)	Nigeria	Harris, 1961
			Senegal	Coutin, 1970; Gahukar, 1980.
		B. fusca	Nigeria	Harris, 1962
	Eupelmus australicus Gir.	*C. sorghicola* (larva-pupa)	Senegal	Gahukar, 1980.
	Eupelmus spp.	*C. sorghicola* (larva-pupa)	Nigeria	Harris, 1961
		G. penniseti (larva-pupa)	Senegal	Coutin & Harris, 1968
7. *Eurytomidae*	*Eurytoma verbenae* Ferr.	*E. gayneri* (pupa)	Senegal	Risbec, 1950
	Systole sp.	*E. gayneri* (larva)	"	"
8. *Ichneumonidae*	*Dentichasmias busseolae* Hein.	*A. ignefusalis* (pupa)	Nigeria	Harris, 1962
	Isotima sp.	*B. fusca* (?)	Sierra Leone	Jordan, 1966
	Syzeuctus spp.	*A. ignefusalis* (larva)	Nigeria	Harris, 1962
			Senegal	Risbec, 1960
	Chasmias sp.	*A. ignefusalis* (pupa)	Nigeria	Harris, 1962
	Trathala flavo-orbitalis Cam.	*M. loreyi* (larva)	Senegal	Gahukar, 1981c
	Pristomerus sp.	*S. exigua* (larva)	Senegal	Risbec, 1950
		H.armigera (larva)	"	Gahukar, 1981c
		E. gayneri (larva)	"	"
	Scenocharops spp.	*Sesamia* spp. (larva)	Sierra Leone	Jordan, 1966
	Charops tegularis Szepl.	*A. moloneyi* (larva)	Senegal	Risbec, 1950

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	Charops sp.	*S. exigua* (larva)	Senegal	Risbec, 1950
9. *Platygasteridae*	*Platygastor* sp.	*G. penniseti* (larva-pupa)	Senegal	Coutin & Harris, 1968
	Aphanogmus sp.	"	"	"
10. *Pteromalidae*	*Norbanus* sp.	*Sesamia* sp. (larva-pupa)	Nigeria	Harris, 1962
	Spalangia pennisetae Risb.	*A. soccata* (pupa)	Senegal	Risbec, 1950
	Spalangia atherigonae Risb.	"	"	"
11. *Scelionidae*	*Platyteleromus busseolae* Gah.	*B. fusca* (eggs)	Nigeria	Harris, 1962
	Platyteleromus hylas Nixon	*A. ignefusalis* (eggs)	Senegal	Risbec, 1950
	Telenomus thestor Nixon	*A. moloneyi* (eggs)	"	"
	Telenomus sp.	*S. calamistis* (eggs)	Ghana	Forsyth, 1966
	Hadronotus pisus Nixon	*E. gayneri* (eggs)	Senegal	Risbec, 1950
Order : Diptera				
1. *Tachinidae*	*Sturmiopsis parasitica* Curr.	*Eldana* sp. (larva-pupa)	Nigeria	Jerath, 1968
		A. ignefusalis (larva-pupa)	Nigeria	Harris, 1962
		Sesamia sp. (pupa)	"	"
		B. fusca (pupa)	"	"
	Sturmia inconspicuella Bar.	*A. moloneyi* (larva)	Senegal	Risbec, 1950

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	Sturmia inconopicua Mg.	S. exigua (larva)	Senegal	Risbec, 1950
	Sturmia sp.	"	"	"
	Palexorista laxa Curr.	H. armigera (larva)	Mali	Doumbia, 1980
		M. separata (larva)	"	"
	Linnaemya angulicornis Speis.	M. loreyi (larva)	Senegal	Gahukar, 1981c
	Goniophthalmus halli Mes.	R. albipunctella (larva)	"	"
2. Sarcophagidae	Sarcophaga villa Curr.	A. soccata (larva)	Senegal	Gahukar, 1981c
	Helicobia destructor Mall.	H. armigera (larva)	"	"
3. Chloropidae	Oscinosoma risbeci Seguy	S. cretica (larva)	Senegal	Risbec, 1950
	Ceratopogon risbeci Seguy	A. ignefusalis (larva)	"	"
	Epimadiza sp.	A. ignefusalis (pupa)	"	"
4. Phoridae	Aphiochaeta xanthina Speis.	S. cretica (larva)	Senegal	Risbec, 1950
	Aphiochaeta sp.	A. ignefusalis (larva)	"	"
	Megaselia sp.	S. exempta (larva)	"	"

TABLE 2 : Predators of major insect pests of sorghum and pearl millet reported from West Africa

Order and Family	Species	Host insect & life stage attacked	Distribution	Reference
Order : Hymenoptera				
1. *Formicidae*	*Dorylus affinis* Sch.	*B. fusca* (larva)	Nigeria	Harris, 1962
Order : Coleoptera				
1. *Carabidae*	*Distichus gagatinus* Dej.	*A. moloneyi* (larva)	Senegal	Risbec, 1950
2. *Coccinellidae*	*Micraspis striata* F.	*R. maidis* (nymph-adult)	Gambia	Bridge *et al*. 1978
Order Hemiptera				
1. *Anthocoridae*	*Orius punctaticollis* Reu.	*C. sorghicola* (ovipositing females)	Senegal	Coutin, 1970a
	Orius sp.	*G. penniseti* (ovipositing females)	"	Coutin & Harris, 1968
Order : Diptera				
1. *Syrphidae*	*Ischiodon aegyptium* Wied.	*R. maidis* (nymph-adult)	Gambia	Bridge *et al*. 1978
Class : Arachnida	*Pyemotes ventricesus* Newfs.	*A. ignefusalis* (larva)	Nigeria	Harris, 1962
	Thomisus sp.	*C. sorghicola* (ovipositing females)	Nigeria	Harris, 1961
	Diaca sp.	"	"	"

TABLE 3 : Pathogens on major insect pests of sorghum and pearl millet reported from West Africa

Group	Pathogen	Host insect and life stage attacked	Distribution	Reference
Bacteria	*Bacillus thuriengiensis* Berl.	*B. fusca* (larva)	Nigeria	Harris, 1962
Fungi	*Metarrhizium anisopliae* (Metsch.) Sorok.	*A. ignefusalis* (larva)	"	"
	Aspergillus flavus Link.	*Raghuva* spp. *Masalia* sp. (larva)	Senegal	Vercambre, 1978
		B. fusca (larva - pupa)	Nigeria	Harris, 1962
	Aspergillus sydowi Thom & Church	*B. fusca* (pupa)	"	"

CURRENT BIOLOGICAL CONTROL RESEARCH AT IITA, WITH SPECIAL EMPHASIS ON THE CASSAVA MEALYBUG (*PHENACOCCUS MANIHOTI* MAT-FER)

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ABSTRACT

Soon after its accidental introduction from Latin America into Africa, the Cassava mealybug, *Phenococcus manihoti* has developed into a major pest, threatening cassava production in most of the Central and West African countries. Since chemical control is not feasible for ecological, as well as practical, reasons, priority was given to research on biological control. IITA is currently carrying out research on the biology, ecology, and population dynamics of the cassava mealybug and the already available natural enemies, in collaboration with national and other international institutes. New methods for mass-cultures and releases are being developed. Courses for special training in biological control practices will be organized by IITA.

INTRODUCTION

The annual African production of cassava is 42 million tons produced on approximately six million hectares. Its production and consumption is generally carried out by low resource farmers and the lower income segment of the population. Cassava tubers provide more than fifty percent of the caloric requirements for 200 million Africans. In addition, the leaves are also used as a preferred vegetable in many regions of tropical Africa.

The cassava mealybug, Phenacoccus manihoti, was first observed in Zaire in 1973. It is believed that the pest was accidently introduced from Latin America. Soon after its introduction into Africa, the cassava mealybug started developing and spreading out quickly from Zaire into countries around the Gulf of Guinea and even further west as far as Senegal.
From the Bas-Zaire, the mealybug is also spreading toward the East, threatening the East African cassava-growing areas. In 1977 the cassava mealybug caused large economic losses and food shortages. It is now a recurrent problem in several Central and West African countries.

P. manihoti has a life cycle from egg to reproductive adult of 24 days at 26° C. and is strictly parthenogenetic. The average fecundity in the laboratory is 440 eggs per female, with a maximum of 750.
The life span of an adult is about 26 days. The mealybug feeds generally (in order of preference) on the stem near the growing point, on petioles, and on leaves. The dispersal of the crawlers and the egg masses occurs passively with the wind. Man helps also in spreading the mealybugs by moving infested planting material.

The populatio dynamics of the cassava mealybug follows a seasonal pattern. During the dry season the population builds up very rapidly to reach a self-destructing level. At this point, which generally occurs before the onset of the rainy season, the population will break down because of a lack of food, overcrowding and entomopathogens. The survivors will eventually resettle on the newly produced shoots at the beginning of the rainy season and maintain themselves in small colonies throughout the cassava fields until the next dry season.

The yield losses caused by the cassava mealybug may be as high as 60% of the roots and 100% of the leaves. These high losses are due mainly to the adverse effect of a saliva toxin injected into the plant during the feeding process which depresses the plant's growth rather than through the high number of mealybugs present on the plant.

IITA and the Cassava Mealybug Biological Control

In 1977, IITA held a cassava mealybug workshop in Zaire, inviting eminent scientists from Africa, Europe, North and Latin America specialized in mealybugs and their biological control. The workshop participants concluded that biological control of the pest would be feasible based upon successful work elsewhere and urged IITA to proceed with this work. The biological control approach to solve the cassava mealybug problem has been advocated by IITA for several reasons. In Africa cassava is grown by small landholders in widely-dispersed plots. Access to many of these plots is difficult. Also, the crop is in continuous cultivation throughout the year and so acts as an excellent host for insects since the plant in several stages of growth may be present in any one area. Due to the way it is grown, it would be very difficult to take a chemical control approach. In the first place, the growers have little access to the required chemcials and equipment. Further, mealybug resistance to chemicals is known to build up rapidly and secondary pest outbreaks may be induced. The fact that the cassava mealybug is exotic to Africa makes biological control even more promising.

The magnitude of the cassava mealybug problem has brought IITA to set up close collaboration with national and international institutions or universities. Special fundings to support the biological control program have been obtained for an initial three-year period.

Action to Date

Research at IITA on the cassava mealybug started one year ago in Ibadan, although preliminary research had been done earlier in Zaire (Leuschner 1978; Nwanze 1979). Our knowledge of the biology and ecology of P. manihoti has been expanded lately by research done in the Republic of Congo (Fabres 1980; Fabres and Boussiengué 1980) as well as by our own research and observations at IITA.

The IITA research team is currently working on the bionomics of the cassava mealybug and of the presently available natural enemies. Efficient methods for mass-culturing of mealybugs and natural enemies, and for the releasing of the latter, are being developed. Studies of the cassava agro-ecosystem are being carried out as well as investigations of the arthropod fauna of areas surrounding cassava fields. Emphasis is given to the life table studies of the cassava mealybug since it is very important to know exactly the population dynamics and the factors regulating it in order to assess the impact of the released natural enemies. The life table data collected prior to the releases are being processed by computer and used in the development of a simulation model, along with data from lab experiments. The simulation model will be used to optimise the timing and number of natural enemies to be released in given areas. Life table data will be collected in all the countries interested in biological control of the cassava mealybug, processed at IITA and release operations planned accordingly.

IITA is collaborating very closely with the Commonwealth Institute of Biological Control (CIBC) to locate the area of origin of the cassava mealybug in Latin America. CIBC entomologists have already found several parasitoids and predators on P. manihoti in South America (Bennett and Yaseen 1980). First trials to rear the parasitoids on P. manihoti in Nigeria did not succeed. However, two predators (Hyperaspis sp. and Nephus biluceruarius) obtained from CIBC are being cultured successfully and the first releases have already been made in Nigeria. The potential areas where P. manihoti could have originated extend from Northern Mexico as far south as Brazil. The systematic exploration currently underway of all those areas will certainly yield P. manihoti and the natural enemies controlling it. To find the origin area of P. manihoti and therefore potential candidates for biological control is, in fact, the most important task and great efforts are made in that direction by CIBC and IITA.

A final very important part of IITA's mealybug biological control program is the training of entomologists. Students and post-doctoral fellows are already involved in the current research at IITA. Courses for entomologists who want to be trained in biological control techniques will be held at IITA. The aim of those courses is to have entomologists with good knowledge of biological control practices in all the countries having cassava mealybug problems. These scientists will be responsible for carryingout, in close collaboration with IITA, the cassava mealybug biological control program in their home countries.

In brief, the role of IITA is, in close collaboration with scientists in Africa and Latin America and other international institutions, to provide scientific leadership to overcome the cassava mealybug problem.

REFERENCES CITED

Bennett, F. D. and M. Yaseen. 1980. Investigation on the natural enemies of cassava mealybugs (Phenacoccus spp.) in the neotropics. Final Report, April 1977-March 1980. C I B C report, 19 pages.

Fabres, G. 1980. Bioécologie de la Cochenille du Manioc (Phenacoccus manihoti hom. Pseudococcidae) et de ses populations en République Populaire de Congo - 2 - variations saisonnières d'abondance. Rapport de l'ORSTOM, Mars 1980. 5 pages.

Fabres, G. and J. Bousiengue. 1980. Bioécologie de la Cochenille du manioc (Phenacoccus manihoti hom. Pseudococcidae) et de ses populations en République de Congo - 1 - Cycle évolutif et paramètre biologiques. Rapport de l'ORSTOM, Mars 1980, 14 pages.

Leuschner, K. 1978. Preliminary observations on the mealybug (Homoptera Pseudococcidae) in Zaire and a Projected outline for subsequent work. Proceedings of the International Workshop on the Cassava Mealybug, Phenacoccus manihoti MAT-FERR (Pseudococcidae). IITA, 1, 1978, 85 pages.

Nwanze, K. F. 1979. Biology of the Cassava Mealybug, Phenacoccus manihoti MAT-FERR in the Republic of Zaire. Proceedings of the International Workshop on the Cassava Mealybug, Phenacoccus manihoti MAT-FERR (Pseudococcidae), IITA, 1978, 85 pages.

THE ROLE OF BIOLOGICAL CONTROL IN THE ORGANIZATION AND IMPLEMENTATION OF THE INTEGRATED PEST MANAGEMENT PROJECT

C.I.L.S.S.

by Jean Tetefort

The project entitled, "Research and Development of Integrated Pest Management Against Principal Food Crop Pests in the Sahel" is financed by USAID and implemented by the Permanent Interstate Committee Against Drought in the Sahel, with technical support from FAO.

The project operates on three levels: national, sub-regional, and regional. It is part of a wider plant protection program having the following objectives:

1. Long Term

- To establish a permanent integrated pest management system against pests found on major food crops (millet, sorghum, corn, rice, wheat, niebe, and peanuts) in CILSS member countries. The application of such a system chould contribute to the growth of agricultural production and the protection of the environment against the indiscriminite use of pesticides.

2. Short Term

a) It is essential that each participating country:

- encourage and promote integrated pest management (IPM) in order to make its principles known, accepted, and applied;

- provide information and carry out training at all levels of agricultural development;

- establish a program of surveillance and control of crop pests by applying integrated control techniques to demonstration areas in the rural sector;

- conduct primary and applied research necessary to the permanent establishment of crop protection programs;

- participate in the training of extension agents and of farmers in the use of new techniques;

- aid in the coordination and cooperation of all disciplines and institutions directly involved in order to facilitate research, development, and implementation of integrated pest management.

b) At the regional, sub-regional, and international levels it is advisable to:

- coordinate all aspects of training, research, development, and implementation relating to IPM. This entails setting up a permanent exchange of information between participating countries and evaluating each one's activities in order to assure a measured attainment of stated goals;

- promote mutual cooperation between countries for the exhange of practical and theoretical information. This cooperation can be achieved through the activities of visiting specialists and through seminars where consideration can be given to decision-making and problem-solving on a national as well as regional basis.

I. Intregrated Pest Management

1.1/ Objectives

IPM is a diverse control system which, according to the particular environment and population dynamics of the species under consideration, utilizes all appropriate techniques and methods in the most compatible way possible. The goal is to maintain pest populations at levels where no economic loss will result. This definition, held by the FAO since September 1967, involves:

- the maximum exploitation of natural mortality factors, to be strengthened using artificial methods if these fail. Natural factors include parasites and predators as well as resistant varieties and improved agricultural practices;

- the application of common pesticides where the risk of surpassing economic thresholds exists. Pesticides are used as a last resort. Their use must be maximally compatible with natural mortality factors and the quantities used be limited to the minimum necessary to complement natural means of control;

-IPM is not dependent upon on specific method of control, but rather, upon the selective application of appropriate technology in harmony with the natural regulating and limiting factors of the environment.

1.2/ Considerations relative to the Environment

Under the present project, IPM techniques to be researched, developed, and applied essentially concern the annual crops already cited. A specific strategy and technique will be applied to each crop, varying according to the pest to be controlled. However, it is clear that the philosophy, principles, and objectives remain the same; only the applications differ as a function of plant, pest, and environment.

Experience acquired over recent years has largely shown that it is impossible to envision phytosanitary problems without taking into consideration the overall environment in which intervention is necessary. This principle became fundamental from the moment is was realized in advanced technological countries that systematic, indiscriminate, or excessive us of pesticides:

- often favored the evolution of new crop pests by creating a biological imbalance between the pests and their antagonists (parasites and predators);

- resulted in insect strains resistant to pesticides, requiring further application of new pesticides;

- polluted the environment to the extent that the health of man and of domestic animals was gravely compromised.

In addition to these drawbacks, one must add the considerable costs of purchasing and using great quantities of pesticides for public services or for agricultural needs.

It is essential that pest control in Africa avoid this path. Within the present framework it is indispensable to examine in minutest detail, the ecological aspects of phytosanitary problems in food crops, (especially cereals) before deciding on intervention methods.

The relative stability of natural ecosystems is due to the fact that they shelter a large number of living organisms which are interdependent through a complex series of interactions. These interactions often take place in the form of competition between species, generally for space and available food. The duration of these phenomena depends, more or less, upon a variety of physicochemical factors in the environment; in particular upon soil and climatic conditions. Each change taking place causes an entire chain reaction, the result of which (relatively long term) is the tendency to return to the original state.

It has been well established that the most simplified ecosystems are thosein which one observes the greatest instability and the largest variations in population levels. This means that one must observe general ecological rules and principles when making any plans for changes in the environment.

Most pests are versatile adversaries, capable of adapting their behavior to their hosts; they can also frustrate any efforts made to combat them. Despite progress in research and technology, one cannot hope for flawless control, much less complete eradication.

The concepts of appropriate pest management include this integrated approach to crop protection, which the project now envisions. Without man's interference, ecological factors in the environment enable crops and their pests to live in a natural equilibrium. Unfortunately, man often destroys this balance to ensure his material needs, by using different methods such as planting new varieties, practicing monoculture, irrigating, etc. When these new practices are not controlled, new pests harmful to crops may appear.

It is recognized that one can largely count on the factors dominating this natural equilibrium in order to introduce integrated control techniques against certain crop pests, even in modern agriculture. So-called "natural" pests play a role much greater than previously though. The sensible choice of control measures will permit these regulating factors to fully exercise their effects, thus obtaining optimum agricultural production with a minimum of chemicals, which are too often detrimental to the environment.

Growing crops of maximum tolerance, with a resistance or capacity for recovery following pest attacks, is essential. Even the best germplasms can be inadequate in dealing with all situations, but a certain resistance provides greater leeway for other strategies within the framework of integrated control. It also provides a certain balance for several years while new biotopes are developing.

Decisions concerning the use of pesticides must be based on estimates of their necessity. These estimates, based on field samplings, should evaluate the degree of economic loss caused by a pest or group of pests, which is acceptable for a specific agricultural area. The need for one or more pesticides must also be determined in order to combat the pests based on a cost/benefit analysis. Costs are to take into account eventual alterations in the biological equilibrium and impacts on the environment.

Two requirements are absolutely necessary to attain these integrated control objectives: a knowledge of economic thresholds and of the biological cycles of crop pests.

The most important undertaking is to determine economic thresholds; in other words, knowing at what level pest damages are no longer acceptable. This is the point where the cost of losses suffered surpasses the cost of intervention, whether it be chemical treatment, biological control, different agricultural practices, etc. In other words, there is no compensation for losses.

Thus, two principal thresholds are to be considered and defined:

- the threshold of tolerance
- the economic threshold of intervention. This being the lowest possible figure, serves as an indicator for intervention.

The principle that the ecosystem should be modified as little as possible must be strictly adhered to. It is therefore necessary to know and understand beforehand the consequences of any action under consideration so that the most appropriate choice will be made. This, of course, will necessitate considerable research efforts.

When considering Sudano-Sahelian cereal production, for example, it should be possible to combine or associate several elements in order to perfect systems requiring a certain degree of monoculture.

The ever-increasing need of food crops for human consumption necessitates the implementation of coherent and balanced production systems, in which phytosanitary intervention will exclusively follow the principles of integrated pest management. There must be a mobilization of efforts at every level to insure success.

1.3/ Projected Measures

In order to attain the objectives of integrated control, the following must be done:

- catalog, study, and exploit the means or resources already used in traditional agriculture to meet local crop protection needs. These should be considered as the primary techniques of integrated control;

- persuade and mobilize the rural population so that all can participate freely in plant protection intervention;

- identify and develop the most effective techniques and methods for crop production and protection;

- obtain the optimum yield beneficial to agriculture and to society at a minimum cost;

- inform the rural population of the presence of organisms which could become potentially harmful to their crops (Acridians, etc);

- demonstrate that even organisms endemic to an area could, at any given moment, become extremely dangerous pests;

- develop coherent and balanced systems of agricultural production in harmony with agro-ecosystems. This would enable one to foresee potential problems that could occur on a long or short term basis. In turn, one could then take any necessary steps at the right time;

- reinforce and fully utilize the advantages of biological control. In other words, those offered by natural enemies;

- protect and preserve the environment to assure that a correct balance be maintained between animal and plant species;

- predict the development of critical crop situations; prevention of insect plagues through the creation of a surveillance and observation network;

- use artificial control methods only where they can be economically and ecologically justified;

- standardize and oversee the use of pesticides;

- Popularize extend and maximize exploitation of work-intensive methods leading to self sufficiency, thus increasing yields in the country's different agricultural regions.

- create and distribute pamphlets or pratical diagrams to popularize agricultural production and protection methods among rural populations.

- provide on-going solutions to pest problems as agricultural development takes place.

- define an agricultural production system, which to a degree or in some aspect, is imperfect harmony with the environment.

- research, develop and implement an integrated pest management strategy using economical and effective techniques.

- reduce malnutrition and famine in rural areas by increasing crop production.

- to this end, promote and develop a genuine policy of auto production and self-sufficiency using work-intensive methods which will permit an increase of food crop yields and assure economic protection against pests.

The permanent establishment of an Integrated Pest Management system will, of course, be a long process. It will be carried out progressively in steps, periods, or phases. Its duration will depnd on implementation at all levels.

Four integrally connected and interdependent phases must be considered. Although these may develop at the same time the duration of each will vary according to the problems encountered. The phases are: Information and Training ; Problem Identification, Research and Development, and finally, Implementation and Implantation.

II. BIOLOGICAL CONTROL - MEASURES TO BE UNDERTAKEN

As already mentioned in the explanation of its principles, Integrated Pest Management is, above all, a rational and maximum exploitation of natural factors of mortality which includes parasites and predators as well as use of resistant strains and improved agricultural practices. Artificial means must only be used as a last resort.

- all pests have natural enemies which play an important role in the control of pest development and reproduction.

- for each species of animal pest (insects, birds, rats, etc.) as for each plant disease, it is essential to record and know its predators as well as other ecological elements.

- initially, the Integrated Pest Management Project will direct all its efforts towards natural enemies of insect pests which afflict the aforementioned food crops.

2.1/ Protection of Existing Natural Enemies

Before formulating or carrying out any biocontrol program, all that already exists in the natural environment must be preserved and protected. To effectively ensure this protection, it is necessary to study all beneficial organisms and their relations to the pest species to be dealt with and to the environment. An analysis should then be made of the natural enemies of each pest species on a given crop.

a) A Listing of Beneficial Organisms

Insects harmful to crops have, depending upon habitats and species, a wide range of natural enemies which can intervene at all stages of development (eggs, larvae, nymphs, or imago). These natural enemies can be classed in the following manner, beginning with the least evolved and progressing towards the most evolved:

- Viruses: comparable to plant viruses. More than 300 known species exist at the present time.

- Rickettsias: Closely related to bacteria by the fact that they are also intracellular more than 20 species have been identified.

- Bacteria: are numerous. They may or may not be pathogenic (Bacillus Popillae, Bacillus thurengensis, etc)

- Fungus : More than 500 species have already been recorded, some pathogenic, some not.

- Protozoa : These are principally species belonging to the ameoba groups, coccus, gregarines, and microsporidians.

- Nematodes: The most common and active belong to the genus Neoaplectana numerous species are known.

- Parasites : These are endo or ecto **parasites, mono** or poly specific. The most numerous are found in the super order Hymenoptera.

- Predators : The most common example of these are ladybug predators of aphids and mealybugs.

- Vertabrate Predators : Extremely numerous, among them: Batrachians, reptiles, birds, and mammals.

Census-taking and identification of species within agro-ecosystems is absolutely necessary. This yields precise information on biological cycles and on the presence or activities of natural enemies. By carrying out these two procedures, interactions between pests and other organisms will soon become clear. It is most import-and to determine the influence of the most common natural enemies upon the populations of major pest species.

A great deal of work has been devoted to entomophagous or pest eating insects. Additional work and research is presently being carried on all over the world. Sahelian countries will no doubt benefit from the experience and the results acquired from these efforts.

Tangible progress is made each year through systematic research, notably on hymenopterous parasites and hyperparasites. From these findings, the effects of entomophagous insects have been determined on several tropical crops (cotton, sugar cane, rice, fruit trees, etc.).

b) An overall analysis of natural enemies for each pest species for a given crop

The brief enumeration of the different categories of pest enemies gives one an idea of the complex phenomena resulting from multiple interactions between these categories. Also to be considered:

- the influence of climate on the success of parasitism

- the presence of hyperparasites

- the competition or, to the contrary, complementary effect, between entomopathogenus and entomophagous genuses, or between two pathogens or two parasites, etc.

- the relative importance of different organisms is strictly dependent upon particular environmental conditions: climate, surroundings, farming and phytosanitary techniques.

It is essential to:

- discover the effects of predation and parasitism

- determine the relative importance of the different species and their characteristics

- study the epizootiology (causes of disease outbreaks) of entomopathogens (viruses, fungi, bacteria, etc)

The analysis of such a biocenosis presents some difficulties, but on the other hand, it will reveal what potential exists for the use of natural enemies against food crop pests.

2.2 Control possibilities using natural enemies and agricultural methods

There are two routes to follow to best profit from the biological potential represented by pests' natural enemies: the first is to reinforce their activities through agrocoenostic intervention, and the second is to use them directly.

Depending on the situation, a combination of indirect and direct action will produce good results. The first route, which is indirect, must be compatible with the type of production planned and must not disturb the environment. The second one involves constraints and risks inherent in the production and large-scale use of living organisms.

In addition, these routes are both subject to economic imperatives. A study must therefore be made showing to what degree they are profitable for agriculture in the Sahel.

A. Indirect actions

Overall, these actions are to modify the environment, change agricultural practices, and promote the survival of natural enemies, particularly during the dry season when there is a lack of food and prey.

a) Improvement of farming techniques and of the environment

Above all, it should be remembered that these changes concern not only pest development, but that of other organisms as well.

By changing the mesological context of pests and diseases, farming techniques can certainly constitute valid, effective, and inexpensive methods of integrated control. These techniques are well-known to farmers but, as they are generally based solely on empirical knowledge, they do not always produce the anticipated results. Certain agricultural practices such as plowing, weeding and irrigating, often have a direct influence (good or bad) on the populations of various beneficial insect species. Early or late planting, depending on the circumstances, can considerably reduce pest attacks. On the other hand, plowing done at certain times of the year can have a detrimental effect on the development of Coccinellidae and Syrphidae, particularly in Europe.

Many adult parasitic hymenoptera are quite responsive to pollinic feeding. Most choose their host plants in the interest of protecting and even multiplying favorable plants in order to maintain the population of useful insects.

Reduction of crop infestations is possible by using plant traps, throughout the field, which insects gather on (a method widely used in China).

Casual or spontaneous vegetation also plays an important role in sustaining pest populations and their parasites throughout the year. This must be taken into consideration when applying farming techniques.

For cereals such as corn, sorghum and millet, the uprooting or burning of the preceding sonson's plants reduces pest attacks the following year.

The use of fertilizers is strongly recommended to increase crop yields. The interaction of mineral fertilization and phytosanitary protection is generally favorable economically. However, an initial coordination of agronomical and crop protection research is necessary to avoid the risk of population growth of certain pest species.

The use of nitrogen fertilizers favors the development of several diseases, particularly those of cryptogamous (sporous) origin. These same fertilizers can affect rodent attacks. Often, better nitrogenous plant food increases the rate of growth of phyllophagous insect populations.

The improvement of all farming techniques must be a priority of the IPM research and development program against major food crop pests in Sahelian countries. Farming techniques certainly are, and will remain, the techniques best adapted to the socio-economic structure of these countries.

b) Improvement of chemical control

Chemical control certainly cannot be conducted rationally, effectively, or economically without prior knowledge of the bio-ecology of the pests to be combated and of the beneficial organisms to be preserved. It is important to note the following principles which must guide any chemical intervention:

1. Economic thresholds

As previously mentioned, these are determined as a function of levels of acceptable damage and of the economic profitability of treatments. One of the fudamental principles of IPM is to apply chemicals only when qualitative and quantitative damages to the harvest constitute justification. What's more, the break-even point for the operation should result in an increased yield at least equal to the cost of both pesticide and application.

Pesticide intervention should only be carried out after due consideration. One must always keep in mind the toxic effects on beneficial organisms, which are often more susceptible than the target pests.

No matter how common or how widely used, pesticides must be tested before being applied. Even before taking this necessary step, the bio-ecology of predators and their parasites must be perfectly known and understood.

The essential role of a surveillance and warning system is to promote timely intervention techniques which are simple, economical, effective, and accessible to the African farmer.

In this light, the precise evaluation of damages and their real consequences constitutes an integral method of pest population assessment.

2. Intervention periods

These are determined according to the developmental stage of both insect and plant. Intervention is generally carried out when the pest is most vulnerable and crops will be least affected.

3. Intervention siting and limitations

There is always a correct time and placefor pesticide use. It is essential to insure that beneficial organisms are not harmed.

4. Preventing pesticide resistance (particularly in insect pests)

Tests of effectiveness against insects will determine the best dosage to be used. These will vary according to the growth stage of the vegetation and of the insect's development. Indications of resistance to or accumulation of certain products must be watched for. Precautions must be taken to avoid phytotoxicity and general toxicity to the environment. It is often preferable to use specific insecticides as opposed to polyvalents.

5. Intervention means

These involve determining those treatments which are best suited (terrestrial, aerial, etc.) In any case, prior experimentation and observation must be carried out under different conditions in order to determine the best means of protection.

B. Biological Control- Preliminary trials for direct use of entomophages and entomopathogens.

Biological control offers certain advantages:

- it avoids environmental pollution, as it only uses living organisms

- Any effects of its use can be predicted, because it uses organisms which have existed in the environment for thousands of years and have been thoroughly tested beforehand

- It provides a definitive solution to pest problems. As a result, it is highly unlikely that the break-even point will not be attained.

a) Choice of Biological Agents

Whether it is a question of choosing predators, parasites, or pathogens, one should be guided by the following:

- high biotic potential
- simple and inexpensive reproduction and rearing
- appropriate voltinism (reproductive capability)
- good resistance to extreme conditions (particularly drought)
- good resistance to antagonistic organisms (hyperparasites).

b) Mass Rearing

Classic forms of biological control are very inexpensive as they entail enriching the environment with beneficial organisms (predators, parasites, or diseases) in order to obtain a permament reduction of the Pest Population level.

Unfortunately, such favorable balances are not easy to establish and require some time. It is therefore necessary in certain cases and under certain conditions to plan more flexible and dynamic use of organisms by introducing them to the field whenever their beneficial effects are needed.

New techniques have been developed in several countries to mass produce and release various beneficial organisms at the right time and in sufficient numbers. This is done in the form of "Periodic Colonization" and "Flood" releases or biological treatments. Considerable progress in all biological fields has now resulted in the undertaking of mass laboratory breeding of certain kinds of insects, as well as industrial production of pathogenic bacteria for use against pests.

There are two methods to consider when mass rearing parasites and predators:

1°/ The mass release of endemic parasites and predators, the goal being to increase natural enemy populations, thus raising the level of protection against depredators. This method is relatively simple and probably the most economical. It involves capturing beneficial organisms in the areas where they are abundant and directly transferring them to a region where they are rare. In certain cases preliminary mass rearing can be done before release.

2°/ The introduction of natural enemies(alloctones) can be equally as beneficial. However, it is essential to study the existing natural enemies before resorting to this method, notably by knowing their distribution.

c) Practical Application of Biological Control

Practical application trials must be attempted and carried out. They will consist of releasing parasites and predators solely in conjunction with treatments using pathogenic organisms (viruses, bacterias, fungi).

The timing and conditions of the releases or treatments are dependent upon yearly climatic conditions, degree of crop infestation, and pest distribution and activity. Only after several years of experiementation and repeated trials will it be possible to define and recommend one or more biological control techniques.

Many countries are now successfully using biological control on several insect species harmful to agriculture, particularly on fruit tree pests. New biological control techniques are used on cereal crops as well. Examples of this follow:

- entomophagous insects such as Trichograms , Parasites of many pest eggs, as well as numerous species of coccinellidae which are predators of mealybugs and aphids.

- Bacterial insects of the Bacillus thurengensis strain used in the same manner as chemical pesticides but without endangering the environment. There are also products manufactured from a specific virus base.

Recent work relating to entomophages, carried out bv Senegalese agronomical researchers with the aid of IRCT, has produced encouraging results in the Nioro du Rip region. The discovery of a native species of Trichogramme, a natural parasite of the Raguva sp. (a millet spike depredator) is particularly important.

The combination of several predatory and entomophagous parasites can sometimes insure better control of pest populations on a given crop.

Natural antagonists and inter-species competition are not the only biological phenomena that can lead to the perfection of control methods. For each pest, it is possible to consider specific intervention techniques based on thorough knowledge of its physiology or better, its ecophysiology. The following methods are among those that are already being used or researched:

- The manipulation of the photoperiod which can upset reproduction (aphids);

- The use of attractants, repellents, or inhibiting food intakes in plants;

- The use of sexual pheromones , many of which have already been isolated. These can be used either as attractants to locate and selectively destroy a sex, or as a means of preventing partners from mating;

- Intervention using hormonal treatments which affect the pest's morphological development, cannot be ignored. During periods of moulting, metamorphosis, and sexual reproduction, it is especially easy to cause disorders and abnormalities which render the pest incapable of survival;

- The use of specific sterilizing agents is also recommended under certain circumstances;

- In addition to this group of synthetic hormones, there is a wide variety of isolated active plant substances which act in a similar manner.

Finally, great efforts have been made in the field of genetic control. The principle consists of introducing into natural populations organisms which carry either lethal genes or cytoplasmic incompatibilities.

These are very complicated techniques and must be carefully followed. In a given agrocenosis, it is possible for a species which has been completely eliminated to be replaced by a species which is even more harmful to the crop (the cure is worse than the disease).

All the biological control methods just reviewed are certainly in current use, but it is essential that they be examined and tested in relation to the overall makeup of each environment.

The possibility of such methods becoming widespread obviously depends on the economics of mass breeding of autocides, entomopathogens, sterilizing agents, and others.

Basic research, currently being conducted on numerous beneficial organisms, is opening the way to the development of methods with practical applications (all of which adhere perfectly to the concept of integrated pest management. However, their impact still remains small. It is often necessary to supplement ecological measures with indirect actions.

III. CONCLUSIONS

Integrated pest management programs against single crop pest of millet, sorghum, corn, etc., can vary within a zone or from one zone to another. This depends on a number of factors such as field dimensions, farming techniques, the variety and the phenology of adjacent or neighboring crops, and the overall important socio-economic factors. These control programs, which are closely related to the larger crop production program, will evolve as new knowledge is acquired. The building process is essentially a dynamic one.

In any case, several operational phases should be considered in order to obtain positive results:

1) identification of the principal elements in the agro-ecosystem

2) knowledge of the development and interaction of the principal animal and vegetable components

3) determination of economic thresholds

4) small scale experimentation to examine the interactions and effects of possible strategies and tactics (experimentation and observation network)

5) large scale practical research to test promising strategies and techniques (demonstration zones and pilot projects)

6) application of surveillance systems and forecasting of plagues

7) implementation of effective strategies and tactics which are available to farmers and harmless to the environment.

When carrying out integrated pest management programs, priority must be given to information, education, training, and animation. This is essential since IPM is a methodology based upon certain fundamental ideas. The program as a whole constitutes a doctrine that researchers, engineers, technicians, administrators, farmers, and any others interested in development, must learn to know or how to use. In effect, highly complex biological systems (agro-ecosystems) must be taken into consideration, and one must know that for every action taken within these systems, a reaction will result.

Before formulating an integrated control method against pests, the user must be capable of difining the ecosystem concerned, analysing the principal elements of that ecosystem, understanding their relationships, and above all, predicting the results of any action taken. Once these conditions are met, there is hope that the ultimate objectives of integrated pest management will be attained: to assure the farmer maximum yields at minimum cost, taking into consideration ecological constraints, the socio-economics of each ecosystem, and the long term preservation of the environment.

Bamako, December 1980

Jean Tetefort.

STEM-BORERS OF CEREALS IN SAHELIAN WEST AFRICA RELATIVE IMPORTANCE AND CONTROL. 1/

KANAYO F. NWANZE

ABSTRACT

A brief account of the distribution and relative importance of the major stem-borer species of cereals in the Sahel is given. The level of parasitism is usually low and populations of the major parasites: Apanteles sesamiae, Pediobius furvus and Terasticus atriclavus increase only towards the end of the growing season. Further investigations on local natural enemies and of exotic species are suggested. Other control measures involving the use of resistant varieties and cultural practices are presented as modalities within the context of a viable integrated pest management program.

INTRODUCTION

The majority of the food crops of the peoples inhabiting the West African Sahelian region is made up of cereals, namely: sorghum, millet, and maïze. Rice is also cultivated but mainly in riverain areas where the land is usually flooded during most of the season. In Upper Volta, cereals constitute 90% of the total agricultural production of which 92% is made up of sorghum and millet, maize 5% and rice 3%. Sorghum and millet contribute 90% of the nutritive energy requirements and constitute the basic food of the population (CILSS, 1978).

There are 3 major constraints to cereal production in the Sahel: rainfall, soil type and fertility, and insect pests and diseases. Annual rainfall is erratic and unpredictable in the Sahel. It is unimodal and ranges from 400-1200 mm over a brief 2-5 month period. Generally, the soils are shallow with a texture ranging from sandy to gravely. They are low in cation exchange capacity and are deficient in phosphate. The principal pest species belong to two orders: Diptera and Lepidoptera. The Lepidoptera which attack graminaceous crops in the Sahel are almost exclusively stem-borers belonging to the families Pyralidae and Noctuidae. However some noctuids are severe

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defoliators, e.g. Spodoptera litorallis and S. exempta. **Raghuva** albipunctella (Noctuidae) attacks millet heads. Within the Pyralidae, Acigona ignefusalis Hmps. is the most serious stem-borer of millet but also has been observed on sorghum. Other Pyralidae include, Eldana saccharina Walk on maize, sorghum, millet and sugar-cane ; Chilo diffusilineus on maize, sorghum, and millet; and C. zacconius Blez. on rice and maize. The noctuid stem-borers of importance are Busseola spp. and Sesamia spp. both on sorghum and maize and Sesamia also on millet.

The taxonomy, biology and bionomics of stem-borers associated with the graminae in Africa are well covered and documented (Risbec, 1950; Tams and Bowden, 1953 ; Bowden, 1956; Ingram, 1958; Harris 1962; Appert, 1964; and Jerath, 1968). A knowledge of the biology, bionomics, alternate host plants, and parasites of the pest species should facilitate the development of control measures that are attainable in West Africa. Nonetheless, the implementation of these control measures should consider field distribution in West Africa, staggered sowing dates which are dependant on the erratic sahelian rains and the economics of application. This paper briefly covers the distribution, and relative importance of the major stem-borer species in the Sahel, discusses various aspects of their control and focuses on the use of parasites and predators as a control component within the framework of an integrated pest management program.

Distribution and Relative Importance

Stem-borer infestation occurs throughout the Sahel but the incidence of occurence is closely related to rainfall. In the drier regions there is a reduction in both the number of pest species and severity of attack on the crop (Table 1).

Busseola fusca F., was observed in Upper Volta in the region below latitude 11° 30' N with an annual rainfall not less than 900 mm, restricting the pest to the South where it has being recovered from maize and sorghum. However in Northern Nigeria this species was observed on sorghum as far north as Kano (12° N and annual rainfall of 575 mm in 1979) and Dutsin-Ma (120 km North-West of Kano). B. fusca does not occur on millet

Acigona ignefusalis is the predominant borer on millet and is more widely distributed in the Sahel than B. fusca. It was not recovered from sorghum in the South but further North at Kamboinsé it replaces B. fusca on sorghum where it is present at a much lesser frequency than either Eldana or Sesamia (Table 1). similar pattern of distribution was observed in Northern Nigeria. A. ignefusalis is practically the only borer species on millet in Niger.

Sesemia calmistis and Eldana saccharina appear to be restricted below latitude 12°N and have not being observed North of Kamboinsé. At Farako-Bâ, S. calamistis is as abundant as B.fusca on sorghum (Table 1) but compared to Acigona it is less abundant on millet. S. calamistis and E. saccharina infestations of sorghum and millet at Samaru are very low.

Early stem-borer infestations of young sorghum and millet plants may result in dead heart and losses in stand (Harris, 1962). Later infestations may affect heading while in fairly mature crops, stem breakage may occur just before harvest.

In Ghana, Girling (1980) found that little damage was done to first rains maize, whereas infestations of S. botanephaga and E. saccharina on the second crop were very high and the Crop was almost completely destroyed. At Kamboinsé, we have found that early planted local millet sustained less damage than the late crop from A. ignefusalis infestation. In Northern Nigeria, B. fusca infestation of sorghum fields was severe in 1980. Leaf damage was very extensive and head production and grain filling were both impeded.

A. ignefusalis infestation of millet in Niger is generally very low and damage to the crop is usually insignificant.

The lowest stem-borer infestation occurs between January and May while major infestation is encountered between August and October during the rainy season.

Usually 2-3 generations of B. fusca and A. ignefusalis are produced during the crop season at Samaru (Harris 1962).Three distinct larvae peaks of A. ignefusalis have also been recorded at Kamboinsé. Usually, when early painted and early-maturing varieties of Sorghum and millet are attacked by the first generation larvae of B. fusca and A. ignefusalis, the damage is insignificant due to low larvae populations. It is the second and third generation larvae which inflict severe losses on late planted and late maturing varieties particularly when a drought period affects growth. The third generation is produced under favorable conditions and this generation goes into diapause in the cut stalks and stubble.

CONTROL

In view of the distribution of farms and the farming practices in West Africa, control measures at the farmer's level should be feasible not only technologically but also sociologically and economically. All methods should be viewed as modalities within a viable integrated pest management program.

Chemical Control

There are difficulties in the use of insecticides: (1) distribution of fields (2) timing of application to coincide with hatching of larvae before penetration into to the stem (3) availability of water (4) cost of insecticides (5) technology of application and availability of trained personnel and (6) toxicity. Cost of insecticides may be subsidized by governments in some countries but if wrongly timed it could interfere with the only effective form of natural control.

Host Plant

The use of resistant varieties of cereals has been poorly exploited. An early attempt was made in Nigeria on maize but was later discontinued. Local varieties of sorghum and millet exhibit a high tillering ability. Borer attack causes most grasses to tiller and tillering is an aspect of varietal tolerance. At low borer infestation the overall head production may be related to tillering ability stimulated in part, by borer attack. It is therefore important that tolerance factors which have been acquired by local varieties should not become eroded during the process of developing higher yield through the introduction of exotic varieties.

Initial attempts should be to screen a representative sample of local Samaru collections, the West African collection and material already proven to be resistant to *Chilo partellus* Zell at ICRISAT Center in Hyderabad, India. The scope and use of resistant varieties are yet to be realized and it is hoped that a program of stem-borer resistant nurseries will be possible at Samaru in 1981.

Cultural Control

In many Sahelian villages, the Practices of saving cereal stems for building houses and fences, for fuel, livestock feed and bedding ensures survival of diapause larvae. The destruction of crop residues and volunteer sorghum before onset of the rains would considerably reduce the initial population of first generation borers. Adesiyun and Ajayi (1980) also found that the mortality of *B. fusca* by partially buring stalks immediately after harvest kills 95% of the larvae with little damage to the stalks. The removal of crop residue and volunteer crop as a measure of control is within the scope of the village farmer and should be encouraged.

Both at Kamboinsé and Farako-Bâ we have seen that damage to cereal crops increases with a delay in planting time in the Sahel is highly dictated by rainfall and its successful application requires farmer education. The uneven use of early maturing varieties or non-uniform application of an aptimum planting date may result in the development of other pest problems. Further-more in most areas extension services are poorly organised or often non-existent.

Biocontrol

A number of parasistes and predators have been recovered from larvae and pupae of stem borers in Africa. The frequency of occurence decreases northwards in the Sahel (Table 1). Ingram (1958) in Uganda reported a high level of parasitism in *S. calamistis* with *Apanteles sesamiae* Cam. as the principal parasite. This parasite was also collected from *B. fusca* and *Chilo zonellus*. Large numbers of *Pediobius* sp (Eulophidae) were recovered from all three borers. The author also claimed that indigenous parasites were probably the main factors controlling *S. calamistis*, but that the incidence of parasitism on *B. fusca* and *C. zonellus* was much lower.

Populations of parasites at Samaru are usually low, but increase only towards the end of the growing season (Harris, 1962). The overall rate of parasitism barely exceeded 10 % of both larvae and pupae and varied considerably from year to year both in species and number. Harris' list consisted of 14 primary parasites mostly in the Hymenoptera, 3 hyperparasites, one predator and 4 diseases which attack eggs, larvae and/ or pupae of *B. fusca*, *Sesamia* spp and *A. ignefusalis*.*Tetrastichus atriclavus* Wtstn., *A. sesamiae* and *Pediobius furvus* Gah. were always present on *B. fusca* and are perhaps the most important species. *Syzeuctus* sp. was regularly recovered from diapause larvae of *A. ignefusalis* and later in the crop season, *Sturmiopsis parasitica* Curran (the only Diptera, listed) and *Hyperchalcidia soudanensis* Steffan are present. One egg parasite, *Telenomous busseolae* Gah. (Scelionidae) was collected from eggs of *B. fusca* at Samaru. *Peymotes ventricosus* Newp. (Pyemotidae, Acarina) was found as an external parasite of diapause larvae of *A. ignefusalis.* Of the diseases ; *Bacillus thurengensis* was the most important on *B.fusca* diapause larvae. Appert (1964) also lists 50 parasites species in the Hymenoptera and ? in the Diptera all recorded in Africa. Of the species listed, *A. sesamiae*, *P. furvus* and *S. parasitica* were common parasites of *A. ignefusalis*, *B. fusca*, and *Sesamia* spp.

In Ghana,Girling, (1980) found that predators, presumed to be "the numerous ants present" were important in removing eggs of *E. saccharina* but parasitism of this pest was only 0.6% during first rains maize and 2.4% on the second rains crop.

Similarly, in laboratory cultures of E. saccharina, parasites accounted for only 1.9% reduction of larvae population. Bordat et al. (1977) in their studies of stem borers of cereals in Africa have also reported several parasites of Chilo zacconius, E. saccharina and S. botanephaga. However in contrast to the others, successful laboratory rearing techniques for parasites, larval and pupal hosts and instances of field releases were reported. In Cameroon, 25% of stem borer larvae were effectively parasitised by a combination of Coelocentrus sp. Tetrastichus Sudanensis Stef. and Hyperchalcidia sudanensis Steff. Similarly, A. flavipes was successfully introduced in Madagascar in 1955, 1960 and 1961 where it resulted in the control of about 50% of the larvae population of Chilo sacchariphagus B.

Although only preliminary studies have been conducted in Upper Volta, of the parasitic species recovered from field collections of B. fusca at Farako-Bâ (Zampalegrè, 1979) and A. ignefusalis at Kamboinsé, the following have been identified as potential control agents: A. sesamiae, Procerochasmia glaucopterus Morl., Trigonogastra sp, Pediobius sp. (Hymenonoptera) and two Diptera: Plethysmochopta sp. and Diploneura sp.

The level of parasitism appears to be higher in East Africa (Mohyuddin and Greathead, 1970) and this may be due to the higher level of stem-borer infestation in that region. Only few parasites in West Africa are known to attack diapausing larvae and/or pupae and thus are able to survive the long dry season. Investigations into the parasitism of E. saccharina and Sesamia spp on wild grasses during the dry season are needed. Biological control has proved to be successful especially in areas where the pest is a recent introduction. Both sorghum and millet are indigenous to Africa and in fact West Africa is a center of origin of both cereals (Bowden, 1976). The borers are well adapted to their hosts which are really also their native hosts - sorghum for B. fusca and millet for A. ignefusalis. One would have expected a simultaneous development of a complex of effective natural enemies well adapted to the annual cycles of their hosts. Therefore there is an area that is still lacking in knowledge on the behavior and ecology of these natural enemies and the scope for the use of exotic species.

CONCLUSIONS

In view of the limitations on the use of insecticides and difficulties in implementing cultural practices, biological control of stem-borers holds a bright prospect as a major compoenent in an integrated pest management program. Resistant varieties may help in reducing pest numbers thereby contributing to the effectiveness of a parasite/predator complex in the final reduction of pest numbers below economic threshold limits.

Initial efforts should be directed towards a comprehensive survey of the pest species and their natural enemies in West Africa followed by a detailed study of their biology and bionomics and an evaluation of their effectiveness as biocontrol agents. The absence of effective local natural enemies will then require the testing of exotic species that have proved successful elsewhere on the same or related host species.

TABLE 1. - Incidence of Stem-borers on Sorghum and Millet in Six locations in Sahelian West Africa.

	Annual rainfall (mm) (1980)	No. stems sampled	% infested stems	Frequency of stem-borer larvae				No. of parasitic diptera[1]	No. of parasitic Hymenoptera[1]
				Busseola sp	Sesamia sp	Acigona igenfusalis	Eldana Saccharina		
MILLET									
Gorom-Gorom	355.3	150	33.1	0	0	100	0	0	0
Kamboinsé (Ouagadougou)	759.8	1000	61.9	0	7.0	84.6	8.4	2.0	13.0
Farako-Bâ (Bobo-Dioulasso)	908.9	620	71.0	0	36.6	55.7	7.7	10.0	44.0
Niamey	-	215	45.0	0	0	95.5	4.5	0	2.0
Maradi	501.8	485	58.6	0	0	100	0	2.0	7.0
Samaru (Zaria)	1183.3[2]	180	68.9	0	3.7	93.2	3.1	0	18.0
SORGHUM									
Kamboinsé	759.8	1000	11.5	0	39.1	9.0	51.7	0	0
Farako-Bâ	908.9	950	77.8	38.9	35.0	0	26.1	6.0	23.0
Samaru	1183.3[2]	520	99.2	98.2	0.5	0	1.3	54.0	126.0

1) Represent total number of larvae and/or pupae (or pupal cases) observed in stems.

2) Data for 1979.

LITERATURE CITED

Adesiyun, A.A. and Ajayi, O. 1980. Control of the sorghum stem borer, *Busseola fusca*, by partial buring of the stalks. Trop. Pest Management 26, 113-117.

Appert, J. 1964. Les chenilles mineuses des céréales en Afrique Tropicales. Agronomie Tropicale 19 : 60-74.

Bordat. D., Brenière J. and Coquard J. 1977. Foreurs de graminae Africaines: parasitisme et techniques d'élevage. Agronomie Tropicale 32: 392-399.

Bowden, J. 1956. New species of African stem-boring Agrotidae (Lepidoptera). Bull. ent. Res. 47 : 415-428.

Bowden, J. 1976. Stem-borer ecology and strategy for control. Ann. appl. Biol. 84: 107-134.

CILSS, 1978. Recherche et Développement de la Lutte Intégrée des Ennemis des Principales cultures vivrières dans les Pays du Sahel.
Draft 20, CILSS Haute-Volta, Jan. 1978.

Girling, D.J. 1980. *Eldana saccharina* as a crop pest in Ghana. Trop. Pest Management, 26 : 152-156.

Harris, K.M. 1962. Lepidopterous stem-borers of cereals in Nigeria. Bull. ent. Res. 53: 139-171.

Ingram, W.R. 1958. The Lepidopterous stalk borers associated with graminae in Uganda. Bull. ent. Res. 49: 367-383.

Jerath, M.L. 1968. Seasonal abundance and distribution of sugarcane stem-borers in Nigeria. J. Econ. Entomol. 61: 593.

Mohyuddin, A.I. and Greathead, D.J. 1970. An annotated list of the parasites of graminaceous stemborers in East Africa, with a discussion on their potential in biological control. Entomophaga, 15: 247-274.

Risbec, J. 1950. La faune entomologique des cultures au Sénégal et au Soudan Français. (Dakar) Govt. gen. A.O.F. 87 pp.

Tams, W.H.T. and Bowden, J. 1953. A revision of the African species of *Sesamia* Guenée and related genera (Agrotidae-Lepidoptera). Bull. ent. Res. 43: 645-678.

Zampalegré, A. 1979. Elements de biologie et dégâts de *Busseola fusca* sur sorgho. Mémoire de fin d'études, Univ. de Ouagadougou, 52 pp.

SLOWING PREIMAGO DEVELOPMENT OF EPHESTIA KUEHNIELLA ZELL. (LEP: PYRALIDAE)

J. DAUMAL, J. VOEGELE, J. BENOIT, AND J. PIZZOL

INTRODUCTION

We have shown (Daumal et. al. 1975) that it is possible to produce large quantities of *Trichogramma* using *Ephestia Kuehniella* as a host. Converting the technique to industrial scale necessitated solving problems of sanitation, and regulating egg production. Development of a unit capable of these tasks, using cold storage of *Trichogramma* in diapause, required detailed studies on the effects of cold on the host in all its developmental stages. Former studies (Voegele et al, 1974) discussed the effect of cold storage on Ephestia eggs; this reports the effects upon larvae and pupae.

Another equally interesting aspect was the search for a cold treatment which could improve Pyralid fecondity while simultaneously causing a more homogeneous rate of development.

We know that females resulting from overwintering *Ephestia* larvae lay greater numbers of eggs than those of Summer (Hassanein § Kahel, 1965) and that 10°C is the most favorable temperature with which to condition several species of Lepidoptera to cold (Takehara 1963-66, in Ashahina, 1969). However, exposure to 2°C causes mortality in larvae of both sexes within 50-60 days (Le Torch, 1977). Somme (1966) emphasizes that while *Ephestia* larvae don't diapause, the hemolymph of the last larval instar undergoes significant modification when exposed to cold. Studies by Cohet (1971-73) on *Drosophila* demonstrate the action of temperature on preimagal development of both sexes. Keeping this data in mind, we investigated larvae and chrysalid conservation at 10°C and the effect cold could have on imagos of Ephestia, and also on the neogregarine colony pest *Mattesia dispora* (Naville) and comportment such as cannibalism.

METHODS AND MATERIAL

Preimago stages are raised in transparent plastic containers 13 cm x 13 cm x 7 cm (height). Each container holds food (i.e. 200 g. of semolina wheat) as well as three packages of eight 11 cm x 2 cm corrugated, cardboard strips held together by elastic bands, and providing 624 refuges. Food is infested with 18 g. or approximately 630 eggs obtained the second night of oviposition and have undergone 86-94 hours of embryonic development. Eggs are aspirated to remove scales and *Mattesia* spores. They are added to an excipiant along with a double volume of fine semolina prior to being sprinkled on the honeycombed cardboard. Addition of 3 cc. water as a fine mist promotes hatching and early feeding.

Containers are placed in 5 series of 18 at a thermoperiod of 26-12°, a relative humidity of 60%, § kept in permanent semi-darkness. Samples are extracted every week after the 31st day of development and placed at a temperature of 10°, and 70% R.H. Caterpillars are only exposed to such cold 31 days of their development because that is the only time that 3rd instar larvae appear , and subsequent phenomena of competition, temperature increase within the commodity, and heterogenetous development (ozer, 1953). While at the temperature of 10°C, lots of 3 containers each are removed after time spans of 0, 7, 14, 28, 56, and 112 days, and placed 20° temperature until emergence, and oviposition (Table II).

DISTRIBUTION OF LARVAL INSTARS WITHIN THE CATERPILLAR POPULATION FOR EACH BASIC TREATMENT.

Due to the heterogenous development of *Ephestia*, we were forced to locate a morphologic characteristic by which different larval instars could be differentiated. We attempted to do this by measuring the maximum width of the top of the head capsule in caterpillars of each treatment group.(Fig.1).

These measurements, when presented as a histogram in divisions of 1/lo mm, show two distinct categories of specimen. One group is composed of 2nd to 5th instar larvae in which head capsule measurements overlap irrespective of instar. The other is composed, exclusively, of 6th instar larvae.

Four other developmental phases can be distinguished quantitatively or qualitatively: the prepupae (immobility of caterpillar and cocoon formation), the young pupae (yellow chrysalid), the old pupae (black chrysalid), and the adult.

A block of 430 specimen, or approximately one third of the treated population is removed from the cold and fixed in alcohol to study population distribution of larval instars, and the other developmental phases just described. Some of the remaining specimen are incubated at 20° to gather adult emergence data. Five pair of adults are removed for fecondity studies at, days 2 and 10, as well as mid-way through the emergence period.

Mating pairs are sampled in a way to obtain at least ten mated pair. Each couple is isolated in a cone and resultant eggs counted each morning after the 5th day of oviposition. The gathered eggs are glued with water to a black paper ring and subsequently placed on a bed of semolina in order to avoid predation by caterpillars and to facilitate the calculation of percent hatch.

One can thus determine the relative proportion of the different instars within the population of each basic treatment, at any given time. For mobile caterpillars, 30-50 measurements are sufficient to determine instar distribution. In figure 3 we show the development at 10°C of populations originally held at different treatments.

FECUNDITY

1. Action of cold. The ean fecundity of five females originating from the beginning of the emergence period (treatment C1) was compared to that from females originating from the middle of the emergence period (Fig.4). This permits the factorial analysis of three variables: A - Exposure to cold at six levels, B- Exposure to five levels of thermoperiod 26-12°, and C- two age groups of emerged females (Table II).

Significant differences were identified for all variables. The superiority of treatment B1 C1 is shown in Fig.4. Caterpillars corresponding to C2 adults had a slower developed and entered 10°C temperature at a more precocious stage than those corresponding to C1 adults.

In that case, young instars (up to 4th) may have the additional potential of tolerating being slowed down by cold treatment, while still being able to complete metamorphosis. These results differ from those obtained by Siddiqui and Barlow, (1972), who were not able to obtain Ephestia development at 12°.

2. Correlation between weight of females and fecundity. Fifteen virgin females from rearing technique B1 A1 and fifteen females randomly selected from treatment B1 A6 were weighed shortly after expulsion of the meconium. They were coupled with virgin males of similar origin. Females were kept at 20°C, and a daily count was kept of number of eggs laid. A strong correlation exists between weight of female and number of eggs laid, as shown in Fig. 5. It is evident that prolonged retention at 10°C favors increased body weight, and allows females to accrue reserves needed for vitellogenesis.

INFLUENCE OF COLD ON ADULT YIELD

Emergence data corresponding to each treatment were recorded daily and retabulated as the percentage of adults obtained from total number of eggs (Table III).

One notes that adult yield is increased by early placement of larvae at a 10°C temperature, followed by prolonged exposure (B1A6 treatment:112 days). This result can probably be attributed to a decrease in cannibalism in that upon emergence from this temperature, the population is made up almost exclusively of immobile prepupae. When a population, however, made up essentially of pupae is exposed to cold (B5 A1), there is a considerable drop in adult yield despite absence of cannibalism.

An examination of all cocoons after the 40th day of emergence indicates that high percentage of emergence corresponds to low mortality (Table IV). In treatments resulting in high yields, the only mortality is that of fully formed adults that suffered from progressive dessication due to the cold.

INFLUENCE OF COLD ON EMERGENCE PATTERNS

We have seen that Ephestia kuehniella has a very heterogenous development. In standard rearing schemes, maintained at 20°C, imago emergence may be spread over a 60 day period. It was interesting to observe the effect of cold upon the duration of emergence (Fig.6). Examining the two treatments B1 A1 (no cold) and B1 A6 (cold during a 4 month period), one notes that 90% of emergence occurs within 14 days in the latter and occurs over 21 day, or half again as long in the former.

INFLUENCE OF COLD ON SPERMATOGENESIS

This variable was studied by Lum (1977) in Plodia interpunctella and Ephestia cautella. Male prepupal and pupal stages were particularly sensitive to exposure to 30°C temperature.

Norris (1933) and Raichoudhry (1936) demonstrated an extreme sensibility of males exposed to 27°C temperature. We have observed an anlogous phenomenon in prepupal males previously exposed to 10°C, but whose metamorphosis and subsequent emergence occured at 20°C. This phenomenon is rare for the storage treatment of greatest interest, B1 A6, which had only one case out of 60 matings, as opposed to treatment B2 A5 which had 13 cases out of 13 matings (up to the 14th day of emergence). Normal hatching started again the 15th day after removal. The effect increased from treatment B4 A5 onward.

If comparative matings in 15 couples composed of males from cold treatment and virgin females from standard rearing technique, no fertile eggs are obtained. When cold treated virgin females are moted to males from standard rearing technique, each female produced about 300 eggs. The males in the first group remained infertile until death. Dissection of females and cold treatment males indicate that the males deposit 1 to 2 spermatophore in the female bursae of copulation. Microscopic examination of crushed testicle however, revealed only the presence of spermatids. No spermatozoides were found in seminal vesicles, copulatory bursae, or in dissected spermatophores, Although they were found in untreated specimen.

This confirms the fact observed by Stockel (1972) in Sitotroga cerealella that after copulating with a sterile or immature male, the female cannot produce eggs. Exposing Ephestia to cold in the post larval stages is fatal to males, but only moderately effects females for the time frames under consideration. Prolonged exposure of female pupae to 10°C cold, however, provokes oosorptive phenomena which decrease fecundity.

The most sensitive stage is the transition of **prepupae** into **pupae** (Fig.3). During this period spermatogenesis is irreversibly effected by cold. On the other hand, male pupae can undergo periods of slowed growth of approximately 40 days without obvious appearance of sterility if the temperature employed permits emergence of imagos (12 to 16°C).

LONG TERM LARVAL STORAGE

These different results prompted us to study the action of prolonged cold on the very young stages of Ephestia. We placed a population of 8,000 first instar larvae at a temperature of 10°C. When after 6 1/2 months we observed that 2-3% of the larvae had become yellow pupae, we removed 4,000 specimen and allowed them to metamorphisize at 20°C. The remaining specimen were placed at 5°C.

The larval population was made up mainly of 6th instars 6.6. and 12.0 mm in average length with mean weights of 33.7 mg and 34.9 mg for male and female, respectively. The fecundity of adults resulting from pupae held at 20°C is comparable to that of previous experiments. Only the first males were permanently sterile. Samples taken after three months' exposure to 5°C indicate that larvae were remaining in a fairly stable state. The mean weight dropped to 29.7 (males) and 30.7 mg (females). Placed at 20°C, these larvae developed into fertile couples averaging 209 progeny in five days. In one out of ten males, we observed abnormal spermatogenesis due to the prolonged exposure to 5°C temperature.

Growth of Ephestia can be sloned for periods up to nine months, with only 20% loss from precocious development.

EFFECT OF COLD ON DISEASES

Spores, the resistant form of protozoa, can resist thermic shocks due to cold temperature without injury. Thus spores of Nosema apis can withstand minus 190°C temperature and still be infectious if returned to 25°C they are destroyed, however, at 45°C. (1976 symposium at Merelbeke, GAND, INRA Bures.)

In larval populations kept at 10°C, we noted no cadavers of caterpillars whose death was due to Mattesia dispora, although this phenomenon is common in mass rearing techniques in which no special prophylactic measures are taken. Thus rearing in prolonged cold may provide gregarine-free larval specimen . In fact, when returned to 20°C to complete metamorphosis, the cold treated last instar larvae already completed all food intake. They merely complete cocoon construction with semolina fragments. It is probably the absence of feeding rather than modification of temperature that prevents subsequent infection.

CONCLUSIONS

Large populations of third instar Ephestia Kuehniella may be kept at 10°C for up to 100 days. Spermatogenesis may be effected if exposed longer. Although this method has the inconvenience of tripling the duration of larval development, it presents important advantages for mass rearing:

- Increase in egg-laying capacity.

- Increase in female fecondity.

- Control of endemic pathogens.

- Reduction in larval cannibalism.

- Tight spread in adult emergence dates.

- Adequate stock of host insects for parasite production.

- Flexibility in scheduling parasite production.

- Infinite multiplications of units.

- Compact size of rearing units.

In such conditions, adult yield is close to 85% with an assurance of increased egg-laying capacity, a female sex ratio of 1, an absence of undesirable pathogens, and the exclusion of bothersome colony pests such as mites, Tribolium, Habrobracon, or Nomeritis.

BIBLIOGRAPHIE

ASAHINA E. - 1969. Frost Resistance in Insects. *Advances in Insect Physiol.*, *6*, 1 - 48.

COHET Y. - 1971. Mise en évidence de l'influence létale de la copulation chez les Drosophiles femelles élevées à basse température. *C.R. Acad. Sc. Paris T. 273 D*, 2542 - 2545.

COHET Y. - 1973. Stérilité mâle provoquée par une basse température de développement chez *Drosophila melanogaster*. *C.R. Acad. Sc. Paris T. 276 D*, 3343 - 3345.

COHET Y. - 1973. Réduction de la fécondité et du potentiel reproducteur de la Drosophile adulte consécutive au développement larvaire à basse température. *C.R. Acad. Sc. Paris T. 277 D*, 2227 - 2230.

DAUMAL J., VOEGELE J., BRUN P. - 1975. Les Trichogrammes. II. Unité de production massive et quotidienne d'un hôte de substitution *Ephestia kuehniella* ZELL. (*Lepidoptera*, *Pyralidae*). *Ann. Zool. Ecol. Anim.*, 7, 1, 45 - 59.

HASSANEIN M.A., KAHEL A.H. - 1965. Biological studies on the Mediterranean flour moth *A. kuehniella* ZELLER (Lep. *Phycitidae*). *Bull. Soc. Ent. Egypte*, *49* ; 327 - 358.

LEIBENGUTH F. - 1970. Veränderungen der Haemolymph aus gewanchsener *Ephestia* Raupen nach Infektion mit *Mattesia dispora*. *Z. Parasitenk.* *33*, 235 - 245.

LE TORC'H J.M. - 1977. Le froid : moyen de protection contre les ravageurs des denrées stockées. Essais de laboratoire sur les insectes des Pruneaux. *Rev. Zool. Agri. Pat. Veg.* *76*, 109 - 117.

LUM P.T.M. - 1977. High Temperature inhibition of development of eupyrene sperm and of reproduction in *Plodia interpunctella* and *Ephestia cautella*. *J. Georgia Entomol. Soc.* *12* (3), 199 - 203.

NORRIS M.J. - 1933. Contributions towards the study of insect fertility. II. Experiments on the factors influencing fertility in *Ephestia kuehniella* ZELLER (*Lepidoptera Phycitidae*). *Proc. Zool. Soc. Lond.* *4*, 903 - 934.

OZER M. - 1953. Contribution à l'étude de la Teigne des farines. Comportement de ponte et comportement alimentaire des chenilles. Ann. Epiphyties IV, 479 - 509.

RAICHOUDHURY D.P. - 1936. Retardation of spermatogenesis and reduction of motility of sperm in Ephestia kuehniella ZELLER (Lepidoptera Phycitidae) caused by high temperatures. Proc. Zool. Soc. Lond. (3), 789 - 805.

SIDDIQUI W.H., BARLOW C.A. - 1972. Population growth of Anagasta kuehniella (Lepidoptera : Pyralidae) at constant and alternating temperatures. Ann. Ent. Soc. Amer. 66, 3, 579 - 585.

SØMME L. - 1966. The effect of temperature, anoxia, or injection of various substances on haemolymphes composition and supercooling in larvae of Anagasta kuehniella (ZELL.). J. Insect. Physiol. 12, 1069 - 1083.

STOCKEL J. - 1972. Stimulus inducteur de la ponte chez les femelles de Sitotroga cerealella OLIV. (Lep. Gelechiidae). C.R. Acad. Sc. Paris T. 275 D, 385 - 388.

VOEGELE J., DAUMAL J., BRUN P. et ONILLON J. - 1974. Action du traitement au froid et aux ultraviolets de l'oeuf d' Ephestia kuehniella (Pyralidae) sur le taux de multiplication de Trichogramma evanescens et T. brasiliensis (Hym. Trichogrammatidae). Entomophaga 19 (3), 341 - 348.

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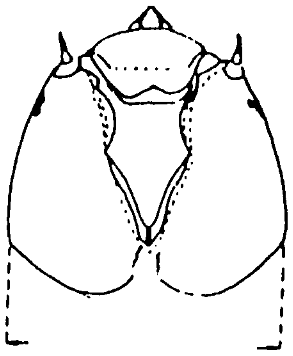


Figure 1: Measurement of Head Capsule, Maximum Width.

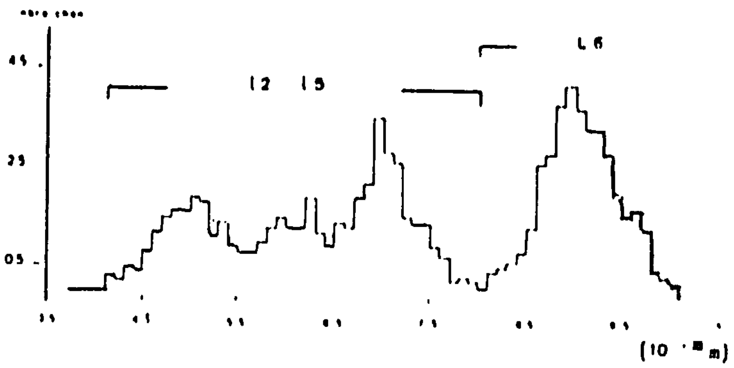


Figure 2: Histogram of head capsule widths, 2nd to 6th instar Larvae, E. Kuehniella.

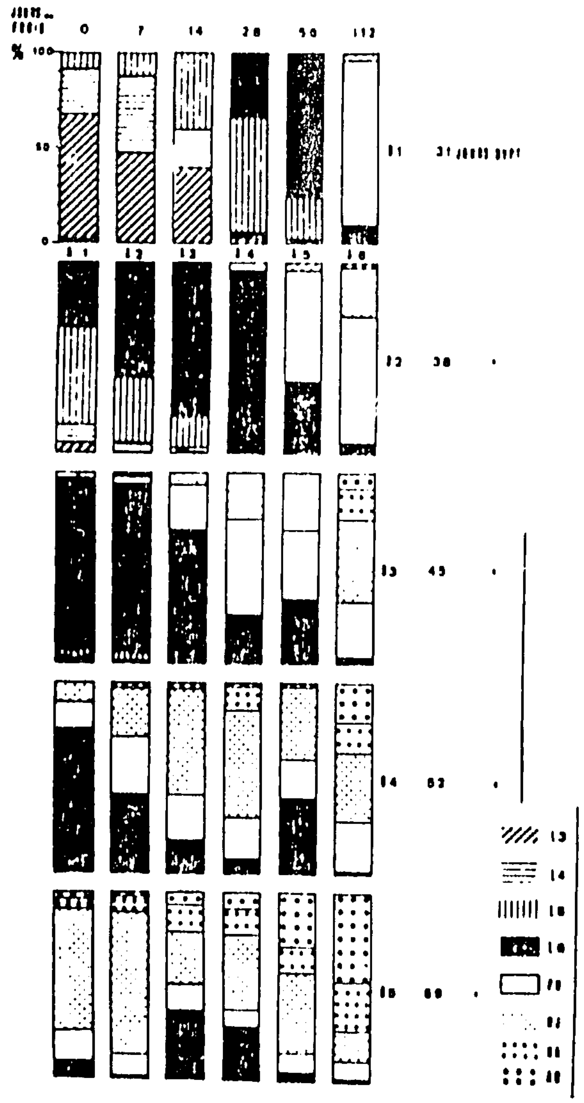


Figure 3: Development of Larval and Post larval populations at 10°C.

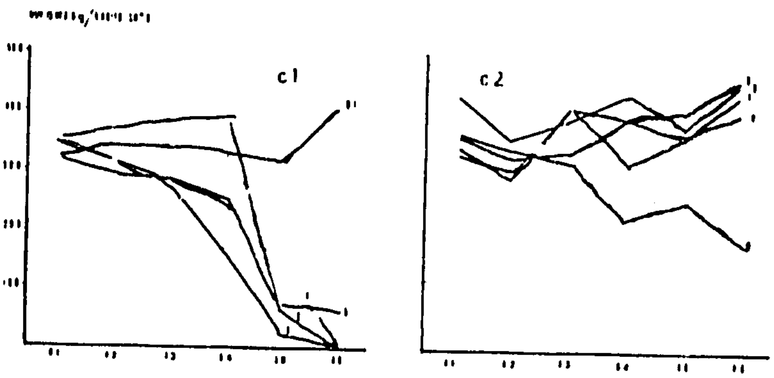
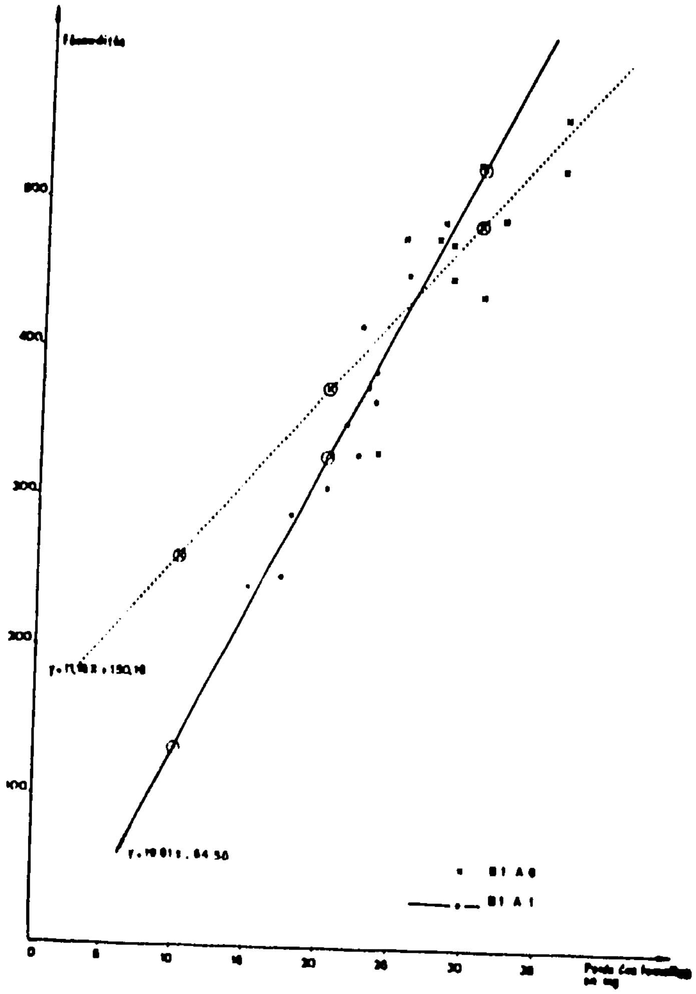


Figure 4: Mean Fecundity.   s.



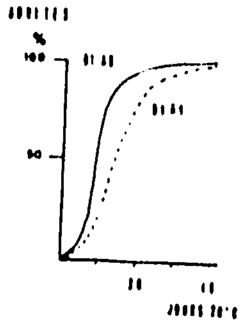


Figure 6: Adult Emergence Patterns.

			SEJOUR EN JOURS A 10°C					
			0	7	14	28	56	112
			A1	A2	A3	A4	A5	A6
SEJOUR	31	B1	A1 B1	A2 B1	A3 B1	A4 B1	A5 B1	A6 B1
A	38	B2	A1 B2	A2 B2	A3 B2	A4 B2	A5 B2	A6 B2
26-12°	45	B3	A1 B3	A2 B3	A3 B3	A4 B3	A5 B3	A6 B3
EN	52	B4	A1 B4	A2 B4	A3 B4	A4 B4	A5 B4	A6 B4
JOURS	59	B5	A1 B5	A2 B5	A3 B5	A4 B5	A5 B5	A6 B5

TABLEAU 1 : Nomenclature des différents traitements élémentaires.

	S. CARRES ECARTS	DDL	S. CARRES MOYENS	F
Traitements	4 668 805	59	79 133	15,4
A	781 070	5	156 214	30,5 **
B	594 515	4	148 628	29 **
C	923 187	1	923 187	180 **
AB	638 758	20	31 937	6,24**
AC	778 602	5	155 720	30,4 **
BC	383 284	4	95 821	18,7 **
ABC	569 467	20	28 473	5,5 **
TOTAL	5 919 191	299		
ERREUR	1 207 465	236	5 116	

TABLEAU II : Analyse factorielle des fécondités.

	A1	A2	A3	A4	A5	A6
B1	70,1	64	78,3	84,8	80,3	95,3
B2	83,4	79,5	73,1	78,4	83,6	77,7
B3	78,7	66,5	73	77,8	79,1	66,7
B4	77,9	63,7	65,5	71,3	81,7	86.8
B5	62	66,7	64,8	54,6	62,1	37

TABLEAU III : Pourcentages d'adultes obtenus éclos.

	A1	A2	A3	A4	A5	A6
B1	9,5	7,3	1,3	0,6	0,0	0
B2	2,2	6	3,3	0	2	1,9
B3	2,4	2,6	1,3	0,6	2	12,4
B4	3,2	14	6,6	9,3	2	11,7
B5	24	20,6	14	22	16,6	43,3

TABLEAU IV : Pourcentage de mortalité au cours de la métamorphose.

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Dakar, Senegal, Feb 9-13, 1981.

The Use of Insect Pathogens in Integrated Pest Management

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SUMMARY

Five basic principles of insect pathology are discussed including the following generalizations: (1) most pathogens are transmitted by ingestion: (2) the host range can be limited to target pest species; (3) pathogens are often inactivated by environmental conditions, but their activity may be enhanced by protective additives; (4) virulence or pathogenicity of an insect pathogen is influenced by the dose administered and the age of the host; (5) the mode of action may be a toxic factor or utilization of the host energy source. Examples of viral, bacterial, fungal and nemátode insect pathogens are gieven as well as their potential for field use. Application of microbial insecticides is also discussed.

INTRODUCTION

Insect Pathology is that branch of Entomology that deals with diseases of insects. It is a discipline which includes the utilization of microorganisms or their byproducts for the control of pest insects. As you are aware, diseases such as small pox, tuberculosis, and cholera have caused epidemics or large decreases in the human population.

Insect pathogens can inflict a similar decimation in an insect population. This is referred to as an epizootic. One of our purposes in Insect Pathology is to manipulate epizootics to our advantage. This can be accomplished in a number of ways: (1) observing an insect population for signs of desease agents, then collecting diseased insects and dispersing them throughout the existing pest population (2) propogating pathogens in the laboratory and then dispersing them into the pest infested zone (3) applying pathogenic byproducts of microorganismic metabolism to surfaces to be contacted by pest species. There are a wide range of disease causing agents at our disposal. The most important of these are viruses, bacteria, fungi, protozoa, rickettsia and nematodes. In actuality, over 1000 insect pathogens have been described (lgnoffo and Hink 1971). Furthermore, it is reasonable to assume that many insect pathogens are still awaiting discovery.

Looking at the historical aspects of Insects Pathology it is noted that we are not dealing with a new science. For example, Aristotle made notations concerning diseases of bees and in 1835 Agostino Bassi demonstrated that the fungus _Beauveria bassiana_ could cause a fatal disease of silkworms. While these early workers dealt with domesticated insects it was only a short time until other investigators were conducting experiments for the manipulation of these disease causing agents. As an example, Metchnikoff demonstrated that the beetle _Anisoplia austriaca_ could be destroyed when infected with the fungus Metarrhizium _anisopliae_ (Steinhaus 1949).

Perhaps our biggest step forward came in 1938 with the marketing of the first commercial microbial pathogen. This preparation was called Sporeine and is a bacterial preparation of the sporeformer Bacillus thuringiensis (Jacobs 1950). Today over 50% of the Cole crops such as cabbage, broccoli, and cauliflower produced in California are protected by preparations of B. thuringiensis.

BASIC PRINCIPLES

What I would like to do today in the time made available is to introduce some basic principles of this important subject, discuss each type of pathogen and review how these principles may be applied in a pest management program.

The five basic principles to be addressed in a microbial control program are:

1. Transmission of the pathogen or how is the disease agent transferred from one host insect to another.
2. Host range of the pathogen - or how many different types of insects can be infected by a particular disease agent.
3. Persistence of the pathogen or how long will the pathogen remain active in the environment.
4. Pathogenicity of the disease agent or what is the doseage requirement for mortalities to occur in an insect population of a given age.
5. Mode of action of the Pathogen - or how does the disease causing agent affect its host.

Firstly, transmission of disease agents most commonly occurs by ingestion of the pathogen. This is the mechanism of transmission for most bacteria, viruses, rickettsia and protozoa.

In some cases, such as fungi and nematodes, the body of the insect may be penetrated by the pathogen through the use of digestive enzymes. Another mechanism of transmission is transovarian transmission. In this type of transmission, the insect egg is infected by disease agents which are present in the reproductive tissues or feces of the female parent. Infections of the emerging immature insect occur by injestion of the disease agent. Some disease agents may also be transmitted by hymenopterous parasites. In this type of transmission the insertion of a contaminated ovipositor may introduce a pathogen into an appropriate host.

The second principle, that of host range is highly variable depending on the particular pathogen under consideration. The bacterium Bacillus thuringiensis, for example, will attack a wide variety of lepidopterous hosts. See Figure 1. Some viruses show this same wide host range while others are very specific . See Figure 2. Perhaps the most important point concerning host range is that non-target organisms such as honey bees, mammals and fishes are not usually affected. Current evidence suggests that most microbial insecticides do not affected. Current evidence suggests that most microbial insecticides do not effect beneficial organisms.

Concerning the persistence of the pathogens it has been shown that high temperatures and sunlight are detrimental to the survival of many of these microorganisms. Smirnoff 1972 and Jaques 1972 have shown severe decrease in activity of viral preparation subjected to ultraviolet radiation. See Figure 3. Bacterial and fungal spores also show similar loss of activity when exposed to unfavorable conditions. The use of protective mixtures has led to prolonged activity of some pathogens (Angus and Luthy 1971). The use of bran baits which shield some of the pathogen from sunlight has also proved successful in field trials (Henry et al 1973). The host cadaver may also play a role in maintaining a disease within the pest population for several generations.

An important point here is the long term effect an insect pathogen will have on a population. In other words, single applications may cause epizootics in many generations of a given pest (Maddox 1973).

The fourth principle - The pathogenicity of the disease agent deals with an expression of the virulence of the pathogen. In simplest terms this represents how effective an agent is in producing death in its host. The more virulent the pathogen the more likely it would be expected that the host would be killed rather than become ill and perhaps recover. Pathogenicity is therefore described in terms of a median lethal dose or LD_{50}. This expresses the dose or number of microbial agents that are required to produce death in one-half of the test organisms. Unfortunately, the LD_{50} alone does not give an accurate description of the total pathogenic effect. Insects respond to increased doseages of pathogens by showing increased numbers infected and increased mortality. See Figure 4. As shown in this dose-mortality curve, the number of dead insects increases with the concentration of the product used. In general terms, the steeper the slope the greater the virulence of the pathogen. Furthermore, the more gentle the slope the greater the variation in response to a given pathogen. Commonly, disease agents produce dose-mortality curves with low slopes. This means that relatively large numbers of pathogens are required to obtain 100% mortality. Figure 5 demonstrates a comparison of slopes for the insecticide DDT and several insect pathogens. The insecticide as expected has a very high slope of 5.5. The pathogens exhibit slopes no greater than 2.8. At first glance it would appear that DDT would be the choice as the best control agent available. However, everyone is aware of environmental consequences of using this compound. What may not be as apparent, however, is that preparations of Bacillus popilliae and Bacillus thuringiensis are very effective in controlling their respective hosts. In addition these slope values do not account for decreases in population due to transmittance of disease from infected females to their larvae or for decreased egg laying.

From Figure 6 it is obvious that a tremendous effect may occur in the second generation that is never reflected in LD_{50} or dose-mortality curves.

Virulence in respect to host age is an important consideration in applying microbial pesticides. Figures 7 illustrates the point that early instars are easier to kill than later instars.

Two examples will be used to illustrate the mode of action of pathogens. These are: 1) Bacillus thuringiensis a spore-forming bacterium and 2) a protozoan belonging to the Microsporida group of the Sporozoa. The process of infection with B. thuringiensis begins with ingestion of the spore and crystal. These elements are contained within the sporangium or remains of the vegetative bacterial cell wall. The basic or alkaline conditions found in the mid-gut of susceptible lepidopterous species initiates the breakdown of the crystal. It is these toxic breakdown products which are responsible for the death of the larva. See Figure 8. The initial reaction in the host is gut paralysis caused by endotoxin. Several other toxins play a role in destruction of the host. These toxins are phospholipase C which destroys gut cells and allows the entry of spores into the hemocoel where they germinate and multiply rapidly; alpha-exotoxin and beta-exotoxin which are released during bacterial metabolism; and gamma-exotoxin which has phospholipase activity.

The mode of action of Protozoans of the Microsporidia group is quite different from the bacterial model. The infection does begin with ingestion of a spore but the similarity ends here. Once, into the gut the spore opens sending the axial filament into the host gut. Through the polar filament emerges a sporoplasm which penetrates the host gut tissues and begins a series of divisions within the host fat body. These division processes as well as the general metabolism of the parasite deplete the host energy sources. It is this depletion of energy sources that causes the death of the host. See Figure 9.

In comparing the two modes of action, it is important to remember that Bacillus thuringiensis kills its host primarily by toxic products of its metabolism while the microsporidian depletes its hosts energy sources. From this it is predictable that B. thuringiensis will cause death of the host in a shorter period of time than the microsporidian.

TYPES OF INSECT PATHOGENS

Although several hundreds of insect pathogens have been described, only a few representative examples will be discussed. These representatives will be taken from viral, bacterial, fungal, protozoan and nematode pathogens.

Perhaps the most promising group of insect pathogens are the viruses. This group has members which range in size from being visible only with the electron microscope to others occurring in aggregates of 15 microns. All members are intracellular parasites, and can not be grown on artificial media such as that used for bacteria and fungi. As the classification of these pathogens is somewhat questionnable, the older terminology will be used. For example, nuclear polyhedrosis and cytoplasmic polyhedrosis will be used instead of Baculovirus.

Nuclear polyhedrosis viruses derive their name from the fact that they multiply in the host cell neucleus. The term polyhedrosis is derived from the observation that several virions or infective virus particles are enclosed in an irregular hedronshaped protein matrix. Most of these virus attack Lepidoptera larvae. At the present time one nuclear polyhedrosis virus has been registered for use as a pest control agent. The commercial name of this preparation is Elcar and is produced by Sandoz Inc. It has been used successfully against all species of the Heliothis genus. It is effective in controlling the cotton bollworm, tobacco bollworm and the tomato fruitworm.

Other viruses which shall not be discussed here are the granulosis viruses, the cytoplasmic polyhedrosis virus and the non-inclusion viruses. None of these viruses have yet been registered but these procedures are underway. Several of these show excellent promise as Biological Control agents.

The most important bacteria currently available as a commercial product are the sporeformers. These are members of the genus Bacillus. the genus name being derived from the rod-shaped vegetative cell. Bacillus popilliae has proved very effective in controlling white grubs. This microorganism is most often used against the Japanese beetle producing a condition referred to as " milky disease".

The term milky disease is used because of the development of bacterial cells within the hemolymph, thus causing the hemolymph to appear milky white. A second member of the genus *Bacillus* is *Bacillus thuringiensis*. This bacterium not only forms a spore but also produces a toxic crystal. The toxic nature of this crystal has been discussed earlier. The advantage of *B. thuringiensis* is that it can be grown on artificial media and under the proper conditions may be stored for 2-3 years. There are presently two commercial preparations of *Bacillus popilliae* available. The trade names of these preparations are Doom and Japidemic. Both are sold by Fairfax Biological Laboratories. Many commercial preparations of *Bacillus thuringiensis* are also available. Two common trade names are Thuricide and Dipel. These are available from Nutrilite Products Inc. and Abbot Laboratories. Other non-sporeforming bacteria will kill insects but most lack the ability to invade host tissues and therefore have not been considered good candidates for biological control programs.

Over thirty different genera of Fungi have been shown to cause disease in insects (Roberts and Yendol 1971). None of these, however, has been produced commercially. Several fungi have shown possibilities as control agents. These are shown in Figure 10. One of the basic problems encountered in the utilization of Fungi for insect control is their strict environmental requirements. Most members survive only under conditions of high humidity and this, unfortunately, limits their use. Perhaps the most logical application would be on water inhabiting species such as mosquitos. In fact, several members of the *Coelomomyces* genus have been shown to substantially decrease mosquito populations.

Figure 11 lists the protozoans that show the most promise for use in controlling insects. At the present time there are no protozoans available commercially, but registration procedures are underway for some species.

Insect-nematode associations are widespread and many reports suggest they play an important role in regulation of insect populations. Figure 12 shows some of the nematodes being considered for biological control uses. Mass rearing of nematode pathogens has delayed their use in control programs despite the fact that some *Neoplectana* sp. have been reared on artificial media. No nematodes are commercially available and none have thus far been registered for use against specific pests.

An interesting discovery showing the association of the bacterium Achromobacter nematophilus and the nematode Neoplectana carpocapsae was made by Poiner (1967). The implication here is that the nematode introduces the bacterium into the host, and both the bacterium and nematode act together to destroy the host.

APPLICATION OF MICROBIAL INSECTICIDES

Microbial agents may be applied as sprays, dusts, and baits. They have also been used in conjunction with chemical insecticides, chemosterilants and pheronomes.

The equipment used for these applications is the same as that used for chemical insecticides, however, it is hoped that equipment designed specifically for use with pathogens will become available. The need for this is due to the formulation of microbial insecticides. Pathogens being insoluble will not behave as chemical insecticides when used in conventional spray equipment.

As with chemical insecticides, microbials are most effective when applied to early stages of the pest. Late instars as shown earlier (Figure 7). tend to be more difficult to control.

Furthermore, since direct sunlight is harmful to some insect pathogens, spray equipment should be adjusted to give good coverage to the underside of foliage. The shade provided by the leaf will thus prolong the activity of the disease agent. Additives such as wetting agents and ultraviolet protectors will also increase the effectiveness of the application.

Timing of application is also important. For example, night feeding species are best controlled by making applications in the late afternoons or early evening. Another consideration is the area of the plant attacked. In species that bore into host plant tissues such as the rice stem borer (Chilo sp.), the insect is vulnerable to control for only a short period. The application of the control agent must therefore be carefully timed to intercept the pest before it moves into the rice stem where it will be more difficult to treat.

LITERATURE CITED

Angus, T. A. and P. luthy. 1971. In "Microbial Control of Insects and mites". In H.D. Burges and N.W. Hussey eds. Academic Press, New York, pp. 591-621.

Bucher, G.E. 1958. Proc. Xth Int. Congr. Entomol. Montreal, 1956. 4:695-701.

Falcon, L.A. 1971. In "Microbial Control of Insects and Mites". H.D. Burges and N.W. Hussey eds. Academic Press, New York. pp. 67-90.

Finney, D.J. 1952. "Probit Analysis". Cambridge Univ. Press Cambridge.

Getzin, L. W. 1961. J. Insect Pathol. 3:2-10.

Henry, J.E., K. Tiahrt, and E.A. Oma. 1973. J. Invertebr. Pathol. 21:263-272.

Ignoffo, C.M. 1968. Bull. Entomol. Soc. Amer. 14:265-276.

Ignoffo, C.M. and W.F. Hink. 1971. In "Microbial Control of Insects and Mites". H.D. Burges and N.W. Hussey eds. Academic Press, New York. pp. 541-580.

Jacobs, S.E. 1950. Proc. Soc. Appl. Bact. 13:83-91.

Jaques, R.P. 1972. Can Entomol. 104:1985-1994.

Maddox, J.V. 1973 Misc. Publ. Entomol. Soc. Amer. 9:99-104.

McLaughlin, R.E. 1971 In "Microbial Control of Insects and Mites". H.D. Burges and N.W. Hussey eds. Academic Press, New York. pp. 151-170.

Poinar, G.O. Jr. 1967. Proc. helminth Soc. Wash. 34:199-209.

Poinar, G.O. jr. 1971. In "microbial Control of Insects and Mites" . H.D. Burges and N.W. Hussey eds. Academic Press, New York. pp. 181-201.

Roberts, D.W. and W.G. Yendol. 1971. In "Microbial Control of Insects Mites". H.D. Burges and N.W. Hussey eds. Academic Press, New York. pp. 125-149.

Smirnoff, W.A. 1972. J. Invertebr. Pathol. 19:179-188.

Steinhaus, E.A. 1949. "Principles of Insect Pathology". McGraw-Hill, New York.

Tanabe, A. M. and M. Tamashiro. 1967. J. Invertebr. Pathol. 9:188-195.

FIG. 1. A PARTIAL LIST OF REGISTERED USES FOR *B. THURINGIENSIS* PRODUCTS

PEST		CROP
	VEGETABLE AND FIELD CROPS	
Alfalfa caterpillar	*Colias eurytheme*	alfalfa
Artichoke plume moth	*Platyptilia carduidactyla*	artichokes
Bollworm	*Heliothis zea*	cotton
Cabbage looper	*Trichoplusia ni*	beans,broccoli, cabbage,cauliflower, celery,kale,cotton, collards,cucumbers, lettuce,potatoes, melons,spinach, potatoes,tobacco
Diamondback moth	*Plutella maculipennis*	cabbage
European corn borer	*Ostrinia nubilalis*	sweet corn
Imported cabbageworm	*Pieris rapae*	broccoli,collards, cauliflower,kale cabbage
Tobacco budworm	*Heliothis virescens*	tobacco
Tobacco hornworm	*Manduca sexta*	tobacco
Tomato hornworm	*M. quinquemaculata*	tomatoes
	FRUIT CROPS	
Fruit tree leaf roller	*Archips argyrospilus*	oranges
Orange dog	*Papilio cresphontes*	oranges
Grape leaf folder	*Desmia funeralis*	grapes

Adapted from Falcon 1975

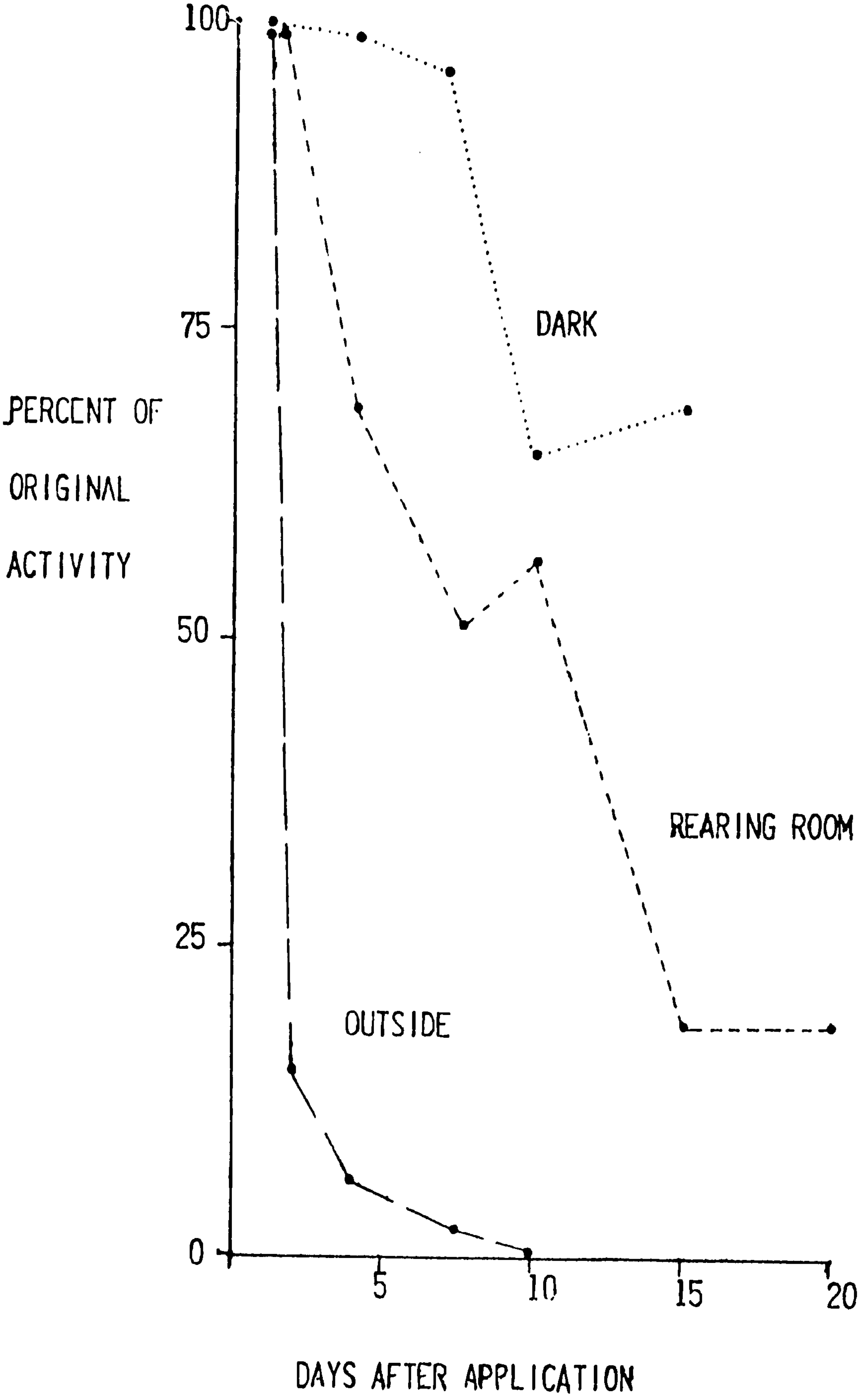
Fig. 2. RELATIVE SPECIFICITY OF DIFFERENT TYPES OF INSECT PATHOGENIC VIRUSES BASED ON ATTEMPTED AND SUCCESSFUL CROSS-TRANSMISSION TO VARIOUS INSECT TAXA

	Number of Cross Transmissions[a]				
	To Alien		To Same		
Virus Type	Order	Family	Family	Genus	Total
Granuloses	0/0	38/1	3/2	4/4	56/6
Nuclear polyhedroses	9/3	137/30	43/26	21/21	187/60
Cytoplasmic polyhedroses	7/2	37/17	2/1	1/1	45/29
Noninclusion viruses	19/18	20/17	9/9	9/9	39/35

[a] Attempted transmissions/successful transmissions

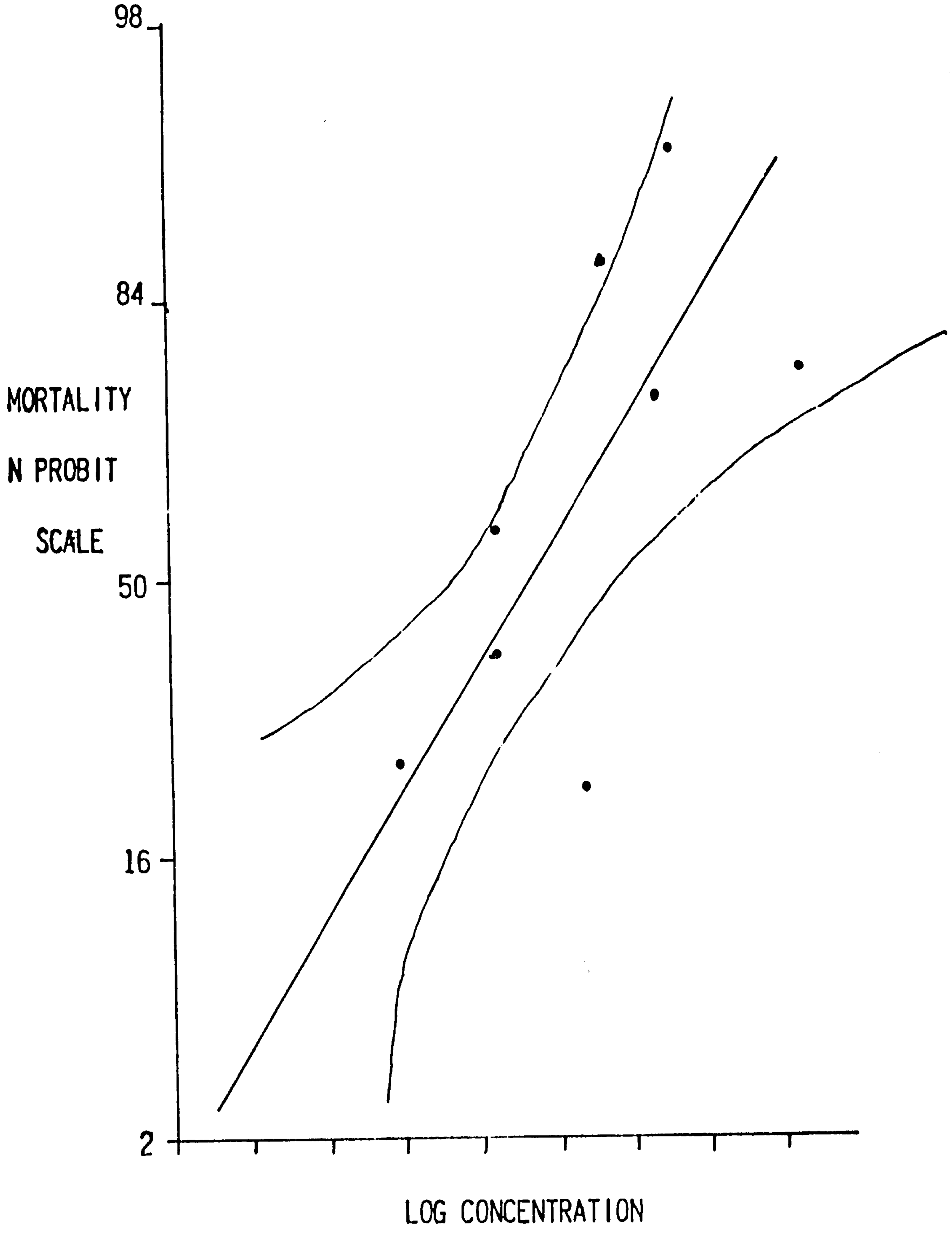
From Ignoffo, 1968

FIG. 3. THE ACTIVITY OF DEPOSITS OF THE NPV OF TRICHOPLUSIA NI



Redrawn from R.P. Jaques 1972

FIG. 4. THE FIDUCIAL LIMITS OF A PROBIT LINE



Adapted from Finney 1952

Fig. 5. THE LD_{50} AND SLOPE OF DOSAGE-MORTALITY CURVES OF INSECT DISEASE AGENTS AND INSECTICIDES

Disease Agent	Host Insect	Method Administered	LD_{50}[a]	Slope[b]
Nosema locustae	Melanoplus bivittatus	Oral	9,000	0.81
Pseudomonas aeruginosa	Melanoplus bivittatus	Oral	19,000	0.83
Polyhedrosis virus	Malacosoma disstria	Oral	300,000	0.86
Bacillus popilliae	Popillia japonica	Oral	2,000,000	1.83
Bacillus thuringiensis	Pieris rapae	Oral	41,000	2.58
Bacillus thuringiensis	Bombyx mori	Oral	2,000,000	2.25
DDT	Musca vicina	Topical	6.2×10^{-3}	5.5

[a] Dose is expressed as number of disease agents or milligrams of insecticide

[b] Slope is expressed as change in value of the ordinate in probits occurring in response to a 10X increase in dose

Adapted from Bucher 1958

FIG. 6. OVIPOSITIONAL CAPACITY AND VIABILITY OF EGGS. TRICHOPLUSIA NI ADULTS INFECTED WITH NOSEMA TRICHOPLUSIAE

	Mean Number of Eggs Laid per Female	Percent Hatch
Uninfected female X Uninfected male	1067	85
Uninfected female X heavily infected male	215.5	0
Heavily infected female X uninfected male	130	34
Heavily infected female X heavily infected male	265	0

Adapted from Tanabe and Tamashiro 1967

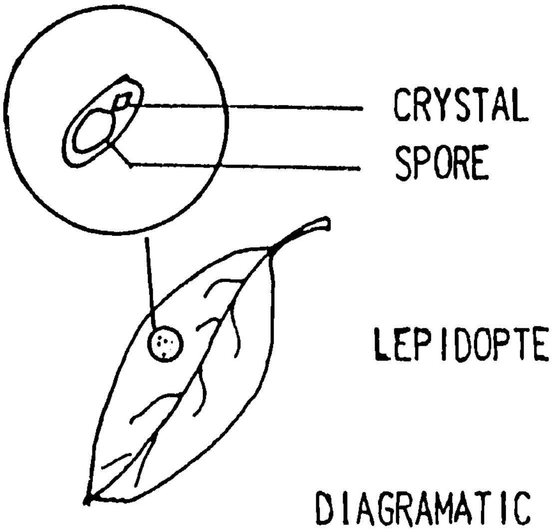
FIG. 7. MORTALITY OF CABBAGE LOOPER LARVAE FROM A DERMAL APPLICATION OF *NOMURAEA RILEYI* SPORES (1 X 10^6 per ml)

Larval Instar	Test Group Size	Mortality from *Nomuraea rileyi* (%)
First	45	58
Second	24	58
Third	23	13
Fourth	48	6
Fifth	24	0

Adapted from Getzin 1961.

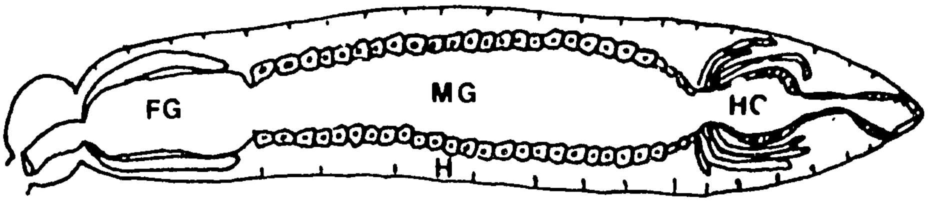
MODE OF ACTION OF BACILLUS THURINGIENSIS CRYSTALLIFEROUS SPOREFORMER

SPORE SIZE APPROX 1u X 4u

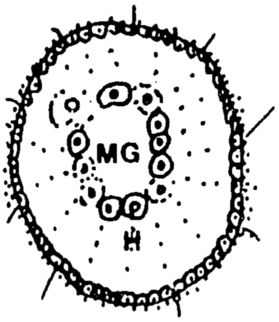


LEPIDOPTERA LARVAE INGESTS CONTAMINATED FOLIAGE

DIAGRAMATIC REPRESENTATION OF CATERPILLAR GUT



INGESTED CRYSTAL BREAKS DOWN IN MIDGUT (MG) CAUSING PARALYSIS (MIDGUT pH IS CRITICAL)



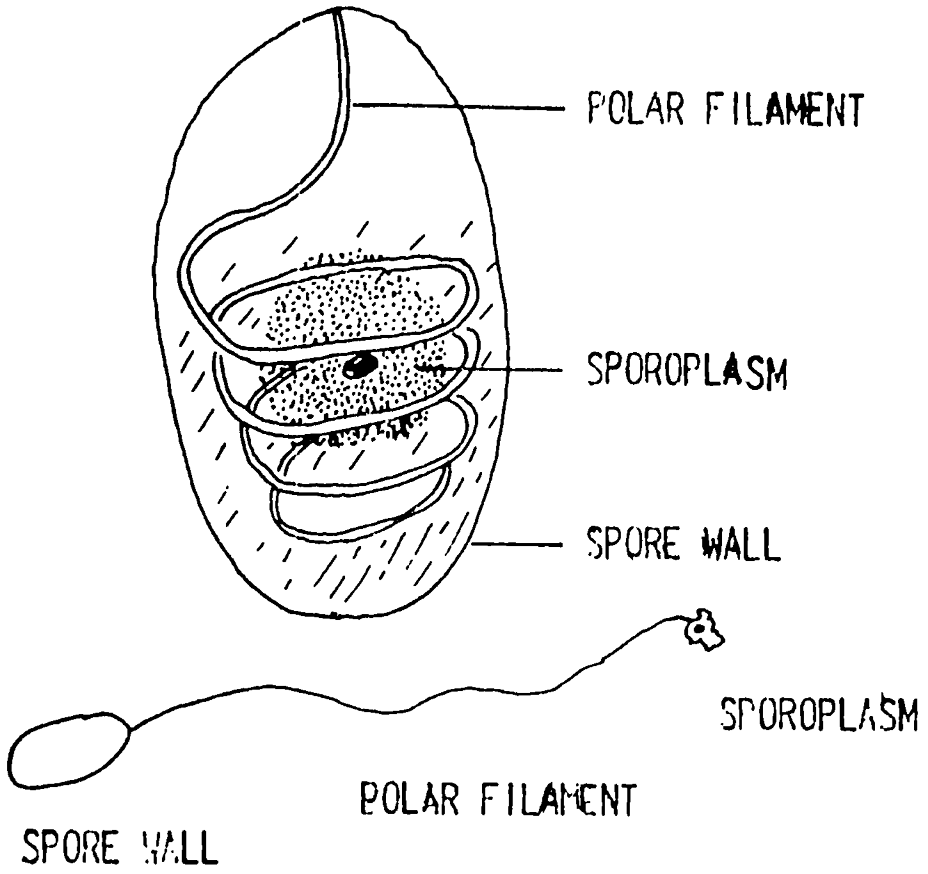
CXS OF MIDGUT AFTER PHOSPHOLIPASE ACTION

BACILLUS GERMINATE IN HEMOLYMPH OF HEMOCOEL (H) AND MAY RELEASE EXOTOXIN

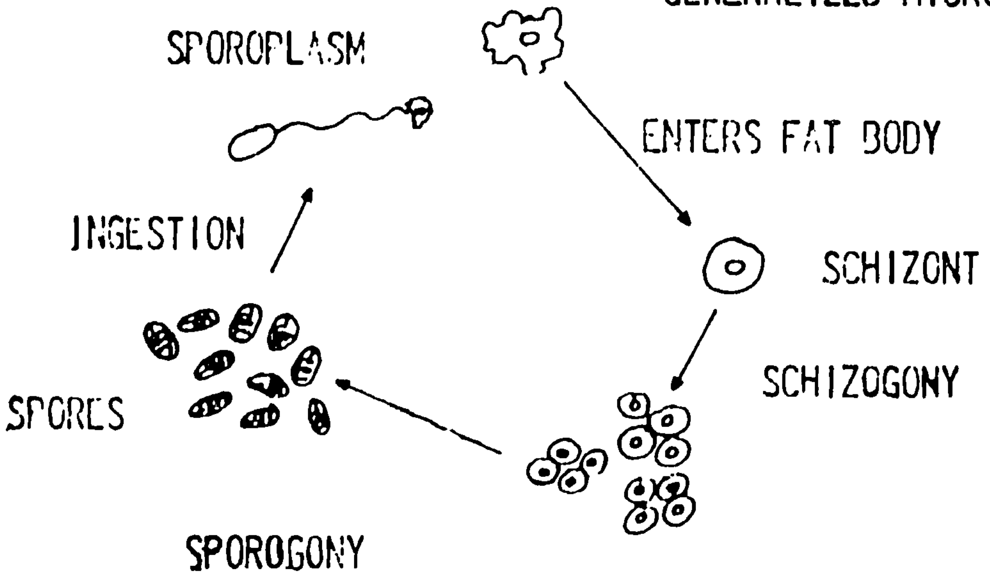
TOXINS

ENDOTOXIN - GUT PARALYSIS (delta-ENDOTOXIN)
alpha-EXOTOXIN - RELEASED DURING METABOLISM
PHOSPHOLIPASE C - BESTROYS PHOSPHOLIPIDS
beta-EXOTOXIN - KILLS LARVAE
gamma-EXOTOXIN - 2°PHOSPHOLIPASE

FIG. 9. MODE OF ACTION OF MICROSPORIDA SP. (PROTOZOA)
SPORE SIZE APPROX 5u



GENERALIZED MICROSPORIDIAN LIFE CYCLE



DIAGRAMMATIC REPRESENTATION OF *NOSEMA SP.*

FIG. 10. ENTOMOGENOUS FUNGI USED FOR MICROBIAL CONTROL

Species	Remarks
Beauveria bassiana	Most widely used fungus
Beauveria tenella	Mostly used against *Melolontha* in soil
Metarrhizium anisopliae	Second most widely used fungus
Paecilomyces farinosus	
Spicaria rileyi	
Entomophthora spp.	Conidia generally too short-lived for use as microbial insecticides; colonization has been attempted
Coelomomyces stegomyiae and *C. indiana*	Insufficient inoculum available for use as microbial insecticide; colonization has been attempted

Adapted from Roberts and Yendol 1975

FIG. II. A PARTIAL LIST OF PROTOZOAN CANDIDATES FOR USE IN MICROBIAL CONTROL

Protozoan	Insect host(s)
Adelina tribolii, *Farinocystis tribolii* and others selected for pests in the total complex	Stored product pest complex
Malamoeba locustae	Suitable grasshopper species
Thelohania hyphantriae	*Hyphantria cunea* and associated susceptible species
Nosema melolonthae	*Melolontha melolontha*
Glugea pyraustae	*Ostrinia nubilalis*
Glugea gasti	*Anthonomus grandis*
Mattesia povolnyi	*Homeosoma nebulellum*
Haplosporidium typographi	*Ips typographus*
Octosporea muscaedomesticae	Muscoid flies
Tetrahymena pyriformis, and *T. stegomyiae*, possibly also *T. chironomi*	Aquatic insects, probably mosquitos, Chironomids

Adapted from McLaughlin 1975

FIG. 12. A PARTIAL LIST OF NEMATODE CANDIDATES FOR INSECT CONTROL

Nematode group or species	Host group or species
Aquatic Mermithidae (*Hydromermis* spp., *Isomermis* spp.)	Culcidae, Simuliidae and Chironomidae
Terrestrial Mermithidae (*Filipjevimermis*, *Hexamermis*, *Agamermis*)	Insects which live in or near the soil
Neoaplectanidae *(Neoaplectana carpocapsae)*	Insects with chewing mouthparts, living on the soil surface or on leaf surface under humid conditions.
Heterotylenchus spp.	Muscoid flies
Deladenus spp.	*Sirex* woodwasps
Tripius *sciarae*	Fungus gnats (Sciaridae)

Adapted from Poinar 1975

AERIAL APPLICATION OF *Bacillus thuringiensis*

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INTRODUCTION

Man-made alterations in agro-ecosystems may cause conflicting situations. The impetuous introduction of monoculture technology in many developing countries, without guidance or previous research and insufficiently perfected technologies, has resulted in low productivity in addition to causing many grave problems, principally with respect to pest control. A new modified approach to the pest control problems must be developed in many countries, including Brazil. Integrated Pest Management (IPM) is a multidisciplinary ecological approach which can provide an efficient system of control which utilizes the ecological factors which regulate pest populations rather than destroying these beneficial factors.

In Brazil, there has been very little contact between pest control scientists and agronomists. Thus, the latter, influenced by chemical pesticides industries, beleives that the chemical control of insect pests is cheaper and easier than any other method. Such behaviour, in addition to the long absence of multidisciplinary teams of specialists, have retarded the development of IPM research programs.

However, during the last five years Brazil has initiated the organization of multidisciplinary research integrating different types of agricultural sciences, including Entomology, Biological Control, Plant Breeding, Plant Physiology, and other disciplines for IPM research programs, principally in soybean. Researches are also being developed with Biological Control in sugar-cane, cotton, wheat, pastures and stored grains. This step is at present stimulating a collaborative effort between different institutions and governmental agencies. Our participation in these research programs concerns the utilization of *Bacillus thurengensis*.

B. Thurengensis, a spore-forming bacterium, is highly pathogenic to a considerable number of lepidopterous pests. Huge quantities of this pathogen are produced commercially to be used as a microbial insecticide. This entomopathogen can be applied as Sprays, dusts or baits, and is considered highly compatible with pheromones, chemosterilants and many chemical insecticides. Products containing B. thurengensis (B. t.) can be applied utilizing equipments similar to those for chemical pesticides. However, there is a great need for the improvement of methods and equipments to obtain uniform coverage of the pathogen in order to insure an efficient control.

GENERAL RECOMMENDATIONS OF AERIAL APPLICATIONS OF B.T.

The application of monoculture technology and, consequently, the necessity for protection against pests, coinciding with the availability of adequate aircrafts and numerous kinds of pesticides, stimulated the adoption of aerial application as an efficient method for crop protection. This method is commonly used in the USA and Canada against crop and forest pests, utilizing chemical as well as microbial insecticides, including B.T.

Here, some general recommendations will be treated. However, details can be found in AERIAL APPLICATIONS OF AGRICULTURE CHEMICALS (Agric. Handbook no. 287, USDA, 1977), CHRISTOFOLETTI (1979), AVAL (1978) and LOURENCO (1979).

The pilot is the principal element for successful application of the control agent. The aircraft has to be operated in approved manner at all times. The pilot must be trained to determine the best direction to apply a block, to know when and how the weather affects the application, and to know his proper limitations in the aircraft he is operating.

In order to obtain uniformity of coverage, the flight lines must be made cross-wind. The pilot must begin treatments on the downwind side of the area. In such a way, he can make each successive swath without flying through product suspended in the air from former applications. Swath marking also is important to give complete coverage. The most common method recommend for swath marking is to have a flagman at each end of the block.

The turnaround maneuver is one of the most critical steps during an aerial application. When wrongly executed accidents may result, most of them fatal. Control of speed of flight during application is extremely important. Once the dispersal equipment has been adequately calibrated, the pilot must maintain the speed constant during application in order to insure uniform coverage.

The recommended height of the flight in crop-lands is between one and two meters. The height must be constant during application to obtain uniform coverage of the treated field. Swath spacing, in the case, is in practice equal to the wingspan of the aircraft. Sprays on forests usually are applied from wingspan height; swath spacing in this case usually is equal to 3 to 4 times the wingspan.

It is important to distinguish between overall swath and effective swath. The first normally is the total span of product deposited in one swath, while the second is the span of sufficient deposit to give a good result of control. The effective swath is more or less one-half of the overall swath, so that some overlapping is necessary. Good deposit uniformity can be obtained by maintaining a pattern shaped like an isosceles traingle and by spacing successive passes of the aircraft at one-half of the overall swath width.

The dispersal apparatus must be calibrated accurately. Proper dosage is a function of speed, swath spacing, and emission rate. Calibration can be made by timing the flow rate of a determined quantity of product or checking the area which can be treated with a measured quantity of product. Size of droplets is important and can be modified. In boom and nozzle system, for example, it can be done by changing the direction of the nozzle orifice in relation to the air stream or, logically, by changing the size of the orifice in each nozzle. Directing the orifice backward produces the largest droplets, forward and downward (45^o) results in the finest ones, and directing the orifice downward produces intermediate size. Obviously, changing the pump pressure modifies the droplet size; increasing it reduces the size, and lowering it increases droplet size.

SPECIFIC RECOMMENDATIONS AND EXPERIMENTAL RESULTS

In Brazil during the last 3-4 years trials of aerial applications of B. t. were undertaken to control Anticarsia gemmatalis (Lepidoptera, Noctuidae) in soybean. The important one was made during the 1979-80 growing season. In this test, two formulations of Dipel (Abbott Laboratories, Illinois, USA), wettable powder and emulsified suspension, were aerially applied to crops in Dourados, State of Mato Grosso do Sul, Brazil (see Table 1.)

TABLE 1 : Aerial treatments with different flow rates and dosages of two formulations of B.t. against *A. gemmatalis*

Treatment	Flow Rate	Dosage	Formulation
T1	10 liters/ha	4.8×10^9 IU/ha	WP
T2	20 liters/ha	4.8×10^9 IU/ha	WP
T3	10 liters/ha	8.0×10^9 IU/ha	WP
T4	20 liters/ha	8.0×10^9 IU/ha	WP
T5	5 liters/ha	4.8×10^9 IU/ha	ES
T6	20 liters/ha	4.8×10^9 IU/ha	ES
T7	5 liters/ha	8.0×10^9 IU/ha	ES
T8	20 liters/ha	8.0×10^9 IU/ha	ES

Control I without any pesticide application

Control II an area treated conventionally with chemical pesticides.

The aircraft used in these trials was IPANEMA (made in Brazil) equiped with Micronair Rotary Units (see Table 2).

TABLE 2 : Specific caracteristics of the micronair AU-3000 dispersing units and flight during application

Emission Rate	VRU[1]	Pressure (psi)
5 liters/ha	9-7-7-9	30,5
10 liters/ha	13-11-11-13	25.0
20 liters/ha	shifted	30.0

1 : Variable restriction unit

Speed 115 miles/hour in all treatment

Height 1.5 - 2.0 meters in all treatments

Assessment of the deposit on Kromekote cards was **undertaken** to evaluate spray coverage in the treatments. A specific tracer dye (Rhodamine) was added to the formulations, and the dyed spots were measured and the number per cm^2 counted to give drop density values for each card. Results of assessment can be found in Table 3.

TABLE 3 : Droplet densities and size in 3 flow rates of aerial application of B. t.

Flow Rate	No. of Droplets/cm2		Size (u)	
	$\bar{x}$	Range	$\bar{x}$	Range
5 l/ha	16.5	17-27	164	93-313
10 l/ha	31.0	13-44	217	106-326
20 l/ha	51.0	36-62	213	133-420

Laboratory tests indicated that Rhodamine had no significant effect on the viability of B.t. (tests of plate counting in Nutrient Agar) or pathogenicity (tests against A. gemmatalis larvae).

Both the formulations were diluted in water immediately prior to application. In these tests molasses was not added, although it can be used as anti-evaporant, as a sun-screen to protect bacterial spores from ultra-violet inactivation, and as ballast to bring droplets down more quickly during application.

The dispersal system was calibrated before application so as to provide the adequate flow rate in the form of droplets 100-200 micron range. Meteorological equipment was mounted to measure temperature (26°C), relative humidity (65%), wind speed (2-5 miles/hour) and direction (north-east) during application.

Corrected mortality in A. gemmatalis larvae due to applications of B.t. is presented in Table 4.

The results indicate that applications of WP with a flow rate of 20 liters/ha of 8×10^9 IU/ha (T4) showed more efficiency than the other treatments. Such a dose corresponds 500 grams/ha of the commercial produot .

TABLE 4 : Corrected mortality em *A. gemmatalis* larvae 48, 96 and 168 hours after aerial application of B.t.

Treatment	Corrected mortality %		
	48 hours	96 hours	168 hours
T1	28.2	23.1	62.6
T2	51.6	34.9	53.3
T3	43.3	41.7	59.9
T4	58.7	68.1	73.3
T5	41.4	27.3	65.0
T6	44.9	33.5	51.0
T7	49.6	42.1	67.0
T8	-	-	17.5

B. t. was applied when the infestation was in an average of 25 larvae per sample, using the drop sheet shake method.

Feeding of *A. gemmatalis* larvae ceased after 6 hours of application, with mortality beginning within 24 hours.

The oil carrier did not affect the viability or pathogenicity of B.t. However, it did not permit an adequate uniformity of deposition under field conditions, resulting in lower mortality than that obtained by the WP formulation with the same dosage.

Our survey of the natural enemies (parasites and predators) in the treated fields, prior to and periodically after application of B.t., showed no effect caused by the aerial application of this entomopathogen. Moreover, the green stink bug, *Nezara viridula*, did not reach its economic injury level in these treated areas due to the availability, maintenance and efficiency of its natural enemies. On the other hand, in the control blocks, the population density of *N. viridula* was much higher and in some locations reached economic injury levels.

Finally, our evaluation of productivity after harvesting confirmed that T4 was significantly more efficient than the other ones. The Productivity of T4 was 30% higher than that of the conventional insecticide treatment (details in Table 5).

The field trials indicated that A. gemmatalis is susceptible to commercially produced B.t., that pathogenicity is not destroyed by type of formulation or carrier, and that it is possible to apply a lethal deposit from aircrafts. Also, the efficiency of aerial applications can be improved if it were possible to extend the viability of spores by protecting them against the ultra-violet radiations, and to reduce the clumping tendency of the suspension.

TABLE 5: Weight of grains obtained from 100 plants and of 1000 grains of each treatment.

Treatment	Weight (g)			
	grains of 100 plants		1000 grains	
T1	2,265.3	a	469.3	ef
T2	2,717.0		484.1	
T3	2,928.5		470.7	cde
T4	3,509.1		493.7	
T5	2,337.6		474.8	b
T6	3,017.0		478.7	
T7	2,181.6		455.8	
T8	2,803.2		467.3	f
Control I	2,248.3	a	469.4	d
Control II	2,430.9		472.7	bc

Same letter means no significant differences (Turkey's test).

READING LIST

AVAL , 1978 - Aviacao Agricola Lencois LTDA. Sistemas de aplicacao , 18 pp.

CHRISTOFOLETTI, J.C. 1979 - Aviacao Agricola: Determinacao da dosagem de aplicacao e voo de calibracao para equipamentos de pulverizacao. Botucatu, 24 pp.

LOURENCO, I.P. 1979 - Aviacao Agricola: Guia para Aplicacoes Aereas. Rio Grande do Sul, 32 pp.

MORRIS, O.N. 1973 - A method of visualizing and assessing deposits of aerially sprayed insect microbes. J. Invert. Pathol., 22: 115-121.

MORRIS, O.N. and M.J. HILDEBRAND , 1974 - Evaluation of commercial preparations of *Bacillus thurengensis* with and without chitinase against spruce budworm. E. Assessment of effectiveness by aerial application, Algonquin Park, Ontario. Can. Dept. Environ. For. Serv. Inf. Rept. cc-X-59.

MOTT, D.G.; T.A. ANGUS; A.M. HEIMPEL and R.A. FISHER, 1961 - Aerial spraying of Thuricide against the spruce budworm in New Brunswick. Can. Dept. For., Entomol. and Pathol. Br. , Bi-monthly Prog. Rept. 17 (3): 2.

SMIRNOFF; W.A.; J.J. FETTES and W. HALIBURTON, 1962 - A virus disease of Swaine's jack-pine sawfly, *Neodiprion swainei* Midd., sprayed from an aircraft. Can. Ent., 94: 477-485

SMIRNOFF, W.A.; J.J. FETTES and R. DeSAULNIERS, 1973 - Aerial spraying of a *Bacillus Thurengensis* - chitinase formulation for control of the spruce budworm (Lepidoptera, Tortricidae). Can. Ent. 105 (12): 1535 - 1544.

Productivity data were collected in collaboration with M.E. Amaral as part of a thesis project on soybeans within the major IPM program.

BIOLOGICAL CONTROL OF WEEDS - POTENTIALS FOR WEST AFRICA

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INTRODUCTION

This paper deals with the direct use of organisms to suppress weeds. Use of resistant varieties, growth regulators, chemicals of biological origin, and competition per se are not considered biological controls for the purpose of this paper. Generally, a biological control organism consumes the plant or part of it for its own existence.

The question is often asked, "Why use biological controls? Are chemical and mechnical methods not more effective?" In the case of some weeds, such as many graminae, chemical and mechanical controls may be more effective. Generally, however, biological control offers the following advantages:

1. Low cost. After an initial relatively high expenditure on research and development, biological control is generally self-perpetuating or can be renewed at low cost.

2. Permanence. Once an organism is introduced, it will potentially maintain itself and attack the weed species perpetually.

3. Spread. The introduced organism will potentially attack the weed species wherever it occurs, even in areas inaccessible to man.

4. Effectiveness. In certain instances, chemical control has been relatively ineffective, either due to the growth pattern of the weed (alligatorweed, Alternanthera philoxeroides (Mart.) Griseb.) or due to the spread and abundance of the weed on relatively low value land (lantana, Lantana camara L. and cactus, Opuntia megacantha Salm. Dyck, on rangeland). Biological agents may overcome these limitations.

Of course, there are some potential disadvantages:

1. The biological control agent may attack only one weed species, leaving other weeds to florish.

2. Generally, the biological control agent will not eradicate the weed.

3. Considerable time is expended prior to release of the agent in testing and clearances.

4. There is no definite assurance at the on set of the biological control program that the weed will be reduced below the level of economic loss.

5. It is difficult to predict the effect of existing natural enemies of the introduced biological control agent. They could nullify the control effect.

6. We cannot invent the biological control agent; it must exist in the world now. It is up to us to discover its existence and prove its potential. Additionally, all weeds do not have an adequate biological control agent as population suppressor.

THEORY

Generally, the most effective biological control programs have been directed against imported weeds, utilizing insects or other enemies imported from the same place of origin as the weed. In many instances, the plant became a weed when freed from pressures from natural enemies in its homeland. Importation of safe and specific enemies to combat this weed could partially restore this pressure, reducing the weed population.

Of course, all the former enemies of a given weed species cannot be considered for importation, since all are not safe. The imported agent must not attack crop plants; indeed, the agent generally must have a "dead end" in its existence. That is, it must be limited to the species or genus of the weed plant, so that it cannot exist without the weed plant. Insects have proven very useful in biological control since most of them developed this specific tie to their host hundreds or thousands of years ago. Other agents utilized, such as fish or manatees, may feed on several species of plants, but are limited by the habitat.

To be effective, the biological control agent should deprive the weed of sufficient materials, energy, or nutrients to affect its survival. This has to be more than a mere pruning action. Often the biological control agent operates in conjunction with a pathogen, in effect, opening the door for the pathogen to enter and destroy the weed. Biological control of waterhyacinth, *Eichhornia crassipes* (Mart.) Solms, and of cactus, *Opuntia* spp., exemplifies this effect.

At the time of release of the biological control agent, the weed population will generally be abundant. The biological agent will necessarily be released in small numbers and will then increase in population on its own. As the biological agent increases to the point of depleting the resources of the host weed species, the weed population will diminish. The biological control agent population some time later will also begin to diminish, since its food and shelter, i.e. the weed, is becoming limited. The diminishing of the biological control agent population then allows some relief in pressure and slight recovery in the weed population, followed in turn by slight recovery in the biological control agent population. This cyclical effect may continue over a period of several years, with populations of weed and control agent gradually diminishing. Biological control programs may thus require 5 to 20 years to bring the weed abundance below the level of economic loss. In some instances, biological interaction or natural limits on the biological control agent may be such as to prevent the cycling from reaching this low point, and additional controls may have to be utilized. This integrated control concept has been widely accepted as necessary in several weed control schemes, such as alligatorweed control. The goal is to reduce weed abundance below a certain economic level. If biological control can do it alone, so much the better. If chemical or mechnical controls must be utilized to further reduce weed abundance, an economy in their use is generally realized due to the additional effect of the biological control agent.

BRIEF HISTORY

Biological control of weeds is not new. Farmers in Hawaii were practicing it on their own before 1900, by moving the Orthezia scale to various patches of the weed, Lantana. Entomologists observing results, advised against moving the scale insects, which also attacked beneficial plants, such as coffee, but undertook themselves to import and utilize safer, more effective insects. In 1902, eight insect species were imported from Mexico and established on lantana, and their effect began to be seen. Although lantana is still abundant in Hawaii and other parts of the world, imported insects have made an impact on it. Today, more than 18 species of imported insects have been established on this weed in some parts of the world.

The most spectacular results were seen in the 1920's in control of the cactus, Opuntia megacantha, in Australia. There, a South American moth, Cactoblastis cactorum, together with a bacterium, devastated the weed, freeing rangeland for continued use. This same insect was later used against cactus in Hawaii with equally spectacular results.

In the 1950's, control efforts were directed against Klamath weed, Clidemia hirta (L.) D. Don, and again spectacular control resulted. In the 1960's, puncture vine, Tribulus terrestris L., alligatorweed, and tansy ragwort, Senecio jacobaea L., were successfully attacked utilizing insects. The 1970's saw control efforts against waterhyacinth and skeletonweed, Chondrilla juncea L., the latter successfully controlled by a rust fungus, Puccinia chondrillinae. Use of vertebrates, such as the white amur fish, Ctenopharyngodon idella, became more widespread in control of submersed aquatic weeds.

POTENTIALS FOR WEST AFRICA

For countries in the process of developing their resources and economic potentials, it would not be practical to undertake a full program of exploration abroad, including research, and development. Rather, it would seem preferable to:

1. Utilize existing animals within the country which may feed on the weeds, such as cattle or fish. Harvesting of the weeds to feed to the animal may be necessary, or "harvesting" or management of the animals may be necessary to maintain the control effect.

2. Import insects or other agents which are already being utilized successfully in the field in other countries.

3. Import insects which have already been adequately developed through exploration and research, supported by another country or organization, but which may not have yet been released in a new country for control of a given weed.

POTENTIAL TARGET WEEDS IN WEST AFRICA

The following West African weed species may be favorable targets for biological control. This listing is not exhaustive, and it should not be taken as a recommendation for importation of natural enemies. It is rather an indication of weeds worthy of intensified efforts in accumulation of necessary information which could lead to importation of natural enemies.

1. Striga hermonthica (Del) Benth. and Striga gesneroides (Willd.) Vatke. These weeds parasitize crop plants. The former parasitizes sorghum, maize, and millet; the latter parasitizes cowpeas. Insects developed by the Commonwealth Institute of Biological Control in India against Striga asiatica (L.) O. Ktze. include the weevil, Smicronyx sp., and the catepillar or moth, Eulocastra argentisparsa. The weevil larvae live in root nodules ,and the caterpillar consumes seed capsules, up to 90 being consumed by a single insect. Tests indicate that the insects would be safe and potentially effective in Striga control. Further testing would be necessary to determine effectiveness against the two weed species of Striga in W. Africa.

2. Chromolaena odorata (L.) R. M. King & H. Robinson. This weed covers fallow plots, many to be utilized in crop planting. The expense of clearing the land by chemical or mechnical methods is often beyond the means of most farmers. Insects developed by the Commonwealth Institute of Biological Control could be useful in reducing abundance of this weed. The insect, Ammalo insulata, from Trinidad is already being tested in India to combat this weed.

3. Lantana camara L. Lantana presents a classic example of biological control. It has already been attacked in some African countries utilizing biological control. More than 18 species of insects are currently available and are used in various countries of the world to combat this weed. These insects originated in Mexico, South America, or the USA.

4. Bracken fern, Pteridium aquilinum (L.) Kuhn. In some highland hill areas, such as Northwest Cameroon, this weed covers rangeland. Organisms which attack ferns will likely be specific and safe. Further exploration and development of biological control agents will be necessary, but the safety potential is very high.

5. Aquatic Weeds. Although all West Africa is not plagued by the aquatic weed problems which occur in other parts of the world, there are bodies of water which contain species of Nymphaea, Pistia, and various submersed weeds in abundance. Biological control agents, including insects, fish, and others have been developed which could be useful should the problem become more acute.

CONCLUSION

In clearing a biological agent for importation for control of a weed, a system of checks and balances is needed. Consultation with experts in entomology, botany, environmental studies, and wildlife management is often necessary. Each concern or objection brought forth by an expert needs to be given its due attention. If the objection is of a very serious nature, it may block the importation of a particular natural enemy. Such an objection may occur in a case of "conflict of interest," i.e; a weed to one individual may be a desirable plant to another. Melaleuca leucadendra (L.) L., for example is an aggressive Australian tree, occupying many parts of the Everglades in Florida, USA, but it is also an important source of nectar for honey. Beekeepers in Florida would likely object to overall reduction in abundance of Melaleuca trees.

Of utmost importance is that decisions to accept or reject a biological agent are made wisely and judiciously. Administrators in responsible positions should definitely consider the potential hazards of importation of a biological agent, but rejections may occur all too often due to ignorance of the benefits of biological control or through rejection of biological control per se, as a control method ,in favor of chemical control or other methods. It is the duty of the scientist responsible for importation to see that his administrators have the necessary information to allow them to make the proper decision.

Generally, an insect being imported for biological weed control is first brought into quarantine. All countries are not equipped with a functioning biological control quarantine room, but modification of an existing room to function as a quarantine room is not difficult or expensive. In quarantine, additional feeding tests may be conducted on plants occurring in the new country which were not tested previously. If further tests are not considered necessary, the insect may be imported into quarantine to rear through to the next generation and thus insure against introducing an unexpected natural enemy. Adults all too often have parasites attached, and their release should be avoided to assure a healthy population of the imported species. The next generation may be obtained as quickly as the eggs produced by these imported adults. The eggs can be surface-sterilized in a hypochlorite + alcohol solution prior to being placed in the field.

Once a release is made, the biological agent and weed populations should be monitored carefully to determine the effect on the weed. All too often, the organism is imported and left to produce whatever control effect it will with little or no monitoring. Results of field surveys should then be made availalbe to other scientists and organizations. At the time of or following the release, specimens should be collected, preserved, and stored in a protected manner, such as in a national or university collection, as voucher specimens, to document precisely the species released.

The following checklist indicates the general procedures followed in importation of a biological control organism. This list may seem overly complicated, and it may be modified or simplified depending upon the organism in question and the procedures normally followed by a particular country.

EXAMPLE OF
CHECKLIST FOR ORGANISM IMPORTATION

Name of organism: ________________________________

Origin ____________________ Distribution ____________

Identified by ________________________________

Responsible researcher in country ______________________
(name and organization)

Responsible researcher or laboratory abroad ________________

____
(name and organization; official in charge)

Quarantine laboratory in country ______________________
(location and official in charge)

Starting date of step in progress

______________ 1. Notify appropriate officials in agriculture of intention to study organism for possible import.

______________ 2. Official response regarding conflict of interest, economic status.

______________ 3. Obtain definitive identification of the biological control organism for importation.

______________ 4. Survey literature to determine its possible host plants.

______________ 5. Assemble collection and distribution records of species from literature, collections, consultations, etc.

_____________ 6a. Submit to officials (a) planned testing procedures, (b) list of test plants, and (c) personnel and documentation of their competence.

_____________ 6b. Submit the same information to officials in previnces where the weed occurs.

_____________ 7a. Official response regarding (a) additional test plants, and (b) other safety considerations, should tests be done abroad or domestically in quarantine?

_____________ 7b. Response of provincial officials.

_____________ 8. Submit to officials a second request after testing abroad, if appropriate.

_____________ 9. Official response recommending (a) additional testing, (b) importation for quarantine testing, or (c) field release in country.

_____________ 10. Submit report to officials if (a) above, after testing.

_____________ 11. Follow importation procedures below if approved:

- a. In country, obtain approval in writing as permits or letter of authorization from quarantine official.
- b. Abroad, receive permits or authorizing letter. Ship clean material in approved containers with permit labels or documents attached. only ship to approved quarantine facilities.

_____________ 12a. After in-country quarantine testing, submit report to officials requesting approval for field release.

_____________ 12b. Submit report to appropriate provincial officials.

_____________ 12c. Inform(or request concurrence of) officials from neighboring countries.

_____________ 13a. Official response accepting or rejecting importation of organism for field release.

_____________ 13b. Response of provincial officials.

_____________ 13c. Response of officials of neighboring countries, if any.

_____________ 14. Receipt in quarantine of first shipment prior to field release.

_______________ 15. Transhipment to release laboratory if other than quarantine laboratory.

_______________ 16. Field release.

_______________ 17. Voucher specimens sent to appropriate collections.

SELECTED READINGS

Charudattan, R., B. D. Perkins, and R. C. Littell. 1977. The effects of fungi and bacteria on the decline of arthropod-damaged waterhyacinth in Florida, Weed Science.

De Bach, P. ed. 1964. Biological Control of Insect Pests and Weeds. Chapman and Hall, London.

Dodd, A. P. 1936. The control and eradication of prickly pear in Australia. Bull. Ent. Res. 27(3): 503-17.

Holm, L., J. V. Pancho, J. P. Herberger, and D. L. Plucknett. 1979. A Geographical Atlas of World Weeds. John Wiley & Sons.

Huffaker, C. B. 1957. Fundamentals of biological control of weeds. Higardia 27, 101-57.

National Academy of Sciences 1976. Making Aquatic Weeds Useful: Some Perspectives for Developing Countries. National Academy of Sciences, Washington, D. C. 175 pp.

Perkins, B. D. 1973. Potential for waterhyacinth management with biological agents. Proc. Tall Timbers Conf. Ecol. Anim. Control Habitat Manage. 4:54-64.

Perkins, B. D. 1974. Arthropods that stress waterhyacinth. PANS 20(3): 304-14.

Perkins, B. D. 1967. Enhancing the effect of Neochetina eichhorniae on waterhyacinth. Proc. 4th International Symposium on Biological Control Weeds.

Perkins, B. D. 1978. Approaches in biological control of aquatic weeds. Proc. 5th International Symposium on Aquatic Weeds. Sept. 1978.

Strong, D. R. 1979. Biographic Dynamics of Insect-Host Plant Communities. Ann. Rev. Entomol. 24:89-119.

Sweetman, L. L. 1958. The Principles of Biological Control, Win. C. Brown, Dubuque, Iowa.

Waterhouse, D. F. and F. Wilson. 1968. Biological Control of pests and weeds. Science Journal 4(12):31-7.

Woods, A. 1975. Pest Control. Halsted Press. N.Y.

Zwölfer, H. and P. Harris. 1971. Host specificity determination of insects for biological control of weeds. Ann. Rev. Entomol. 16:159-78.

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The Value of Nosema locustae in Control of Grasshoppers

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I. INTRODUCTION

Grasshoppers are the most serious invertebrate pests of rangelands in western United States (Hewitt, 1977). Economic infestations presently may be controlled by aerial applications of chemical insecticides. Besides the problem of increasing costs of chemicals and application, chemicals have been criticized because of possible harm to the environment, particularly adverse effects on existing natural antagonists of grasshoppers. These concerns have provided the incentive for development of control strategies, such as microbial pesticides, as alternatives to total reliance on chemicals.

Like most insects, grasshoppers are associated with numerous pathogenic microorganisms that could be useful in their control. The microorganisms include bacteria, fungi, viruses, and protozoa. Bacteria and fungi occasionally cause spectacular epizootics that destroy grasshopper outbreaks, however their dependence on particular temperature and high humidity requirements limits their use in the semi-arid regions of the world where grasshoppers are most destructive. Protozoa and viruses have received more emphasis because they are less likely to be influenced by climatic conditions. A number of these organisms have been isolated from grasshoppers. However, financial and physical restraints to our research effort preclude the development of all these organisms simultaneously.

II. CRITERIA FOR EMPHASIS ON N. locustae

The criteria used as a basis for emphasis on N. locustae for microbial control of grasshoppers included (a) virulence (b) host range, (c) potential for mass production and prolonged storage, (d) adaptibility to low cost application techniques, (e) suitable persistence in the host habitat, and (f) potential for registration as a pesticide.

A. Virulence:

Low densities of grasshoppers usually can be tolerated. The ideal approach then to grasshopper control would be to apply pathogenic microorganisms when densities of an expanding population are low in order to prevent or reduce the extent of outbreaks. However, this approach is not feasible because land owners and operators will not invest money to prevent grasshopper outbreaks. They know that densities may fluctuate drastically from one season, or generation, to the next and that control may not be necessary. Therefore, a microbial control agent will be applied during outbreaks and so must provide sufficient short term control to reduce densities to near or below economic thresholds.

Nosema locustae is an intracellular parasite that infects the fat body of grasshoppers and literally competes with the host for the energy reserves. It is one of the least virulent pathogens of grasshoppers. Laboratory studies established that the LD_{50} at 24 days postinoculation of 3rd instar nymphs of Melanoplus sanguinipes is about 5×10^5 spores (Mussgnug, 1980). Field studies have demonstrated that applications of 2.47 billion spores of N. locustae on 1.86 kgm wheat bran per ha will cause about 50% reduction in grasshopper densities within 4 weeks following application (Henry, 1971; Henry et al., 1973; Henry and Oma, 1974). This initial reduction usually would be sufficient to reduce grasshopper densities to near or below the economic threshold.

B. Host Range

Of the 30 to 50 species of grasshoppers that may occur in an outbreak only 5 or so usually are predominant and considered as economically important. These predominant and economically important species might belong to several different subfamilies of grasshoppers with very different physiological and behavioral characteristics. Therefore, the microorganisms should infect most, if not all, species in order to infect the important species. However, it equally is important that the host range be limited to grasshoppers and close relatives, not only for purposes of safety, but also so as not to infect other natural enemies.

Following the description of N. locustae in Locusta migratoria migratorioides from cultures in England, Canning (1953, 1962) extended the host range to include Schistocerca gregaria and 5 species of grasshoppers from North America, including economically important M. sanquinipes, M. bivittatus and Camnula pellucida. Henry (1969) extended the host range to include 58 species of grasshoppers, a cricket, and a pygmy locust. The list of grasshoppers now includes species that belonged to the major subfamilies, all economically important species, and the Mormon cricket, Anabrus simplex, which occasionally is economically important in western United States. It appears that most species of grasshoppers and some species of crickets are susceptible to infection by N. locustae.

C. Mass Production and Prolonged Storage:

Outbreaks of grasshoppers frequently occur over extensive areas and control agents must be applied to the entire outbreak area in order to be effective. Large quantities of the microbial must be produced and for efficient use of facilities and personnel, production should be continuous and spores should be stockpiled until needed. This requires that the microorganism be capable of withstanding prolonged storage without serious loss in viability.

The relative ease of mass-producing N. locustae was a principal reason for initially selecting it for development as a microbial insecticide. Successive improvements in production techniques have steadily increased the number of spores obtained from each grasshopper. In the current production scheme hatchlings of M. bivittatus are reared in groups of 200 to 300 through the first molt then are transferred to large screened cages. They are fed lettuce, seedlings of balbo rye, and wheat bran. Fifth instar nymphs are fed lettuce sprayed with spores (ca. 10^6 spores/300 nymphs) for 2 consecutive days and again on the 4th day. This causes 99% infection. At 14 to 20 days postinoculation the grasshoppers are dispersed into groups of 2 or 3 adults to reduce cannibalism. These are usually fed fresh lettuce and wheat bran at 3-day intervals. These grasshoppers are terminated at 32 days postinoculation by freezing and the cadavers are stored at -10°C. For processing they are thawed, crushed in a wheat mill, suspended in distilled water, the suspensions agitated to release spores and then passed three or four times through cheese cloth and cloth screens to remove large tissue fragments. The spores are concentrated and cleaned by differential centrifugation and stockpiled in distilled water at -10° C.

In one production test, cages initially seeded with about 2000 second instar nymphs of M. bivittatus yielded 300 to 500 infected adults. Most mortality occurred soon after second instar nymphs were placed in the cages and after inoculation. Spores multiplied best in adults, and females contained more than males. The average was $3.90 \text{X} 10^9$ spores per grasshopper. At the standard application rate of $2.47 \text{ X } 10^9$ spores per ha, average production per grasshopper was about 1.6 ha. Improvements in rearing technology could significantly increase spore production per adult because some heavily infected females contained $2 \text{ X } 10^{10}$ spores.

Studies have established that spores stored in distilled water at -10°C for 3 years or dry in cadavers at -10°C for 1 year were only 10% and 1%, respectively, as effective in field tests as fresh spores (Henry and Oma, 1974). These studies demonstrate the need for developing effective storage procedures. Vavra and Maddox (1976) recommended storage in liquid nitrogen for microsporidians that can withstand freezing, which includes most species from terrestrial hosts. They stored three such species for 7 years with only 2-3% loss in viability. This procedure is currently being tested with N. locustae.

D. Adaptability to efficient low-cost application techniques.

Unlike intense agricultural areas where the gross returns per ha are hundreds of dollars per year, which permits extensive insect control, the average gross return on rangeland in the U.S. is less than $12.00 per ha per year. For this reason land operators are reluctant to control grasshoppers even under cost-sharing arrangements with the state and federal governments. Efficiency is increased and per ha costs reduced when large areas are treated that permit long runs, 32 to 80 km, and wide swaths, up to 150 to 600 meters, using large aircraft. The pathogen must be formulated in highly concentrated preparations that permit operationally efficient payloads.

As with most microbial agents, the infective stage of N. locustae (the spore) must be ingested by the grasshopper. Therefore, spores are formulated with wheat bran which is then applied by aerial or ground equipment. There are some disadvantages in using a carrier such as wheat bran in applying N. locustae, particuarly in comparison to possible application as ultra-low-volume (ULV) sprays. These include the extra expense of formulation with bran, the added cost of handling such a bulky material, and the reduced payloads of airplanes due to the greater bulk. However, these are more than offset by the advantages. For example, full ground coverage is not required in the application of N. locustae on wheat bran, as it is required for suitable control by aqeous formulations, and treatment of missed areas is not necessary. Also, ULV spray applications are restricted to early morning hours when the temperature is such that thermals are not produced. The thermals are updrafts of warm air that cause loss of the spray droplets through drying and drift. Normally this restricts large aircraft to one load per suitable day for ULV applications in western United States. In contrast wheat bran with spores can be applied throughout the day in high temperatures and winds that would prohibit spray applications. Such increased efficiency in use of airplanes and their crews lowers the cost of applications. Also, studies have shown that about 10 times the number of spores used in wheat bran applications are required in ULV sprays (water) to achieve comparable results (Henry et al., 1978). Therefore applying spores in ULV sprays would increase the per ha production cost by 10 times which would exceed the additional cost of using wheat bran as a carrier.

E. Suitable persistence in the environment of the host.

There are two aspects to the persistence of the microbial in the host's environment. The first deals with the short-term persistence immediately following application when the naked spore is exposed to detrimental physical factors, the most serious being solar radiation. Microsporidian spores usually are inactivated within several hours of continuous exposure to ultra violet radiation (Brooks, 1979). _N. locustae_ undoubtedly reacts similarly. However, during applications of _N. locustae_ most of the wheat bran is consumed by grasshoppers within 2 hours. Also, wheat bran flakes are somewhat flat and possibly half of the spores are protected from sunlight. Most importantly, field applications always have resulted in measurable density reduction and infections, which demonstrates that short-term persistence is not a serious problem.

The second aspect of persistence involves the long-term control potential. Because _N. locustae_ reduces host densities only 50 to 75 percent during the season that it is applied it must persist in order to control grasshoppers of subsequent generations. Henry and Onsager (1981) demonstrated that _N. locustae_ persists and continues reducing host densities at least one season following the season of application. Ewen and Mukerji (1980) also demonstrated reductions in grasshopper reproductive levels and persistence in the subsequent season in Canada. Additionally, in a natural enzootic area in the U.S., N. locustae persisted at high levels for 5 seasons and until host densities declined to levels that no longer supported transmission of the organism (Henry, 1972). It seems reasonable that this also can be expected following initiation of artificial epizootics.

F. Potential for registration as a microbial insecticide.

Just as chemical insecticides are registered for use, microbial agents also will be registered for applied uses. In the U.S., authority for registration rests with the Environmental Protection Agency. This agency is establishing standards for safety, efficacy, allowable residues, etc., for all microbial agents. A pathogen should then exhibit characteristics that indicate probable success in satisfying these requirements for registration.

A number of safety tests with N. locustae have been completed in vertebrates, including acute inhalation in rats, acute dermal toxicity in guinea pigs, primary skin irritation in rabbits, long-term feeding with rats, and acute LC_{50} treatments of rainbow trout and blue gill sunfish (Henry and Oma, 1980). It did not reproduce or accumulate in the tissues of these animals, indicating little prospect that it would infect warm blooded animals. Honey bees also are immune to N. locustae (Menepace et al., 1978). However, there is not information about possible effect of N. locustae on parasites or predators of grasshoppers.

Efficacy of chemical insecticides and most microbial insecticides is based on the resulting mortality or density reductions within the population of target species. This method is not suitable for N. locustae because (a) the objectives have been long-term density control rather than short-term control, (b) N. locustae develops slowly and the resulting mortality occurs over an extended period of time, and (c) grasshoppers are irregularly distributed and are capable of moving relatively long distances en masse, which increases the difficulty of detecting density reductions. Basing efficacy on infection in certain key species, such as predominant and economically important grasshoppers, appears both meaningful and reliable.

Based on this information, which is documented in a series of publications from the Rangeland Insect Laboratory as well as from other laboratories, the EPA recently granted conditional registration of a commercial pesticide containing spores of N. locustae for use against rangeland insects [Federal Register 45(94:31312-3]. Several other registrations are pending.

III. INTEGRATION OF N. locustae WITH CHEMICAL INSECTICIDES.

As mentioned previously, N. locustae was selected for development as a long-term control agent to prevent or reduce grasshopper outbreaks. However, land managers are aware of the seasonal variations in grasshopper densities and they withhold control actions until there is a serious threat to existing vegetation. N. locustae will not provide the rapid population control needed to prevent forage loss during outbreaks.

Based on some earlier ideas about integrating N. locustae with chemical insecticides or more virulent microbial agents (Henry, 1970) recent tests have established that N. locustae is compatible with low concentrations of malathion (Mussgnug and Henry, 1979), carbaryl, dimethoate, and carbofuran (Mussgnug, 1980). Tests have demonstrated that wheat bran formulated with N. locustae (1.25 X 10^9 spores per kgm bran) can be tank-mixed with wheat bran formulated with carbaryl (20 gm/kgm wheat bran) for simultaneous application. The objective of this integrated approach is significant short-term control that will reduce grasshopper densities to tolerable levels while also establishing N. locustae at levels necessary for long-term control.

In one such test, large blocks of rangeland were treated by aircraft with wheat bran formulations of N. locustae and/or 2% carbaryl. Treatments were N.

locustae, carbaryl, and 1:2 and 2:1 mixtures, each applied at a total of about 1.86 kgm wheat bran per ha. At 48 hours postapplication, control averaged 66, 59, and 42% for the 3 respective doses of carbaryl. A mathematical model that assumed only 73% vulnerability to the bait had predicted control to within 2 percentage points of these observed averages, indicating that these tank mixed formulations can be changed for use in varying situations of grasshopper densities and control needs. Efficiency of the wheat bran was estimated at 16%, or about 6 flakes per dead grasshopper. The model indicated that such treatments would be more economical when the efficiency of individual flakes was increased (through better formulation technology) which would then reduce the rate of application (Onsager et al., 1981a).

In that test, the results were encouraging to development of grasshopper management programs based on mixtures of *N. locustae* and chemical insecticides. In particular, certain grasshopper species that produce inoculum readily appeared less susceptible to the carbaryl-wheat bran formulation than some species that produce less inoculum and therefore are immediately expendable from the standpoint of long-term population suppression (Onsager et al., 1980). Also, results demonstrated that the longevity among grasshoppers that survived the carbaryl treatments was significantly shorter than among grasshoppers in untreated plots with similar densities. This reduced longevity appeared to be associated with an enhancement of the predator:prey ratio by selective elimination of grasshoppers. The straight treatment of *N. locustae* also reduced grasshopper longevity, both during the season of application and during the subsequent season, but no effects on longevity were evident in the mixed treatments (Onsager et al., 1981b). Although these results generally confirm the expectations of the integrated approach, further experimentation is required to establish, more precisely, the ratios of the tank-mixed formulation that will produce the maximum overall effects.

IV. CONCLUSION

Research on *N. locustae* continues to show a potential for its use in grasshopper control, particularly when integrated with certain chemical insecticides that will provide some short-term control. A very appealing affect of this approach is the indicated preservation of the existing natural antagonists, such as insect parasites and predators, that complement the action of the applied control agents. Overall, this integrated approach appears to be a highly suitable alternative to our present total dependance on chemical insecticides for grasshopper control.

Most of the research with *N. locustae* has been in relation to grasshopper situations in the United States. Cooperative studies with Argentina are providing results that *N. locustae*, alone and integrated with chemicals, will be effective for control of grasshoppers in that country. Similar results might be expected in other areas of the world, including West Africa. However, this cannot be predicted until some initial field tests are completed. Based on experience in Australia, the primary question may not be whether the grasshoppers are susceptible to *N. locustae*, which most are, but rather if they will consume wheat bran or some other carrier. Definitely, these initial tests should be undertaken because *N. locustae* could be very useful for grasshopper control in these areas.

LITERATURE CITED

Brooks, W. M. 1979. Production and efficacy of protozoa. Biotech. Bioeng. 22:91-116.

Canning, E. U. 1953. A new microsporidian *Nosema locustae* n. sp. from the fat body of the African migratory locust *Locusta migratoria migratorioides* R. & F. Parasitology 43:287-290.

Canning, E. U. 1962. The life cycle of *Nosema locustae* Canning in *Locusta migratoria migratorioides* (Reiche and Fairmaire), and its infectivity to other hosts. J. Insect Pathol. 4:237-247.

Ewen, A. B., and Mukerji, M. K. 1980. Evaluation of *Nosema locustae* (Microsporida) as a control agent of grasshopper populations in Saskatchewan. J. Invertebr. Pathol. 35:295-303.

Henry, J. E. 1969. Extension of the host range of *Nosema locustae* in Orthoptera. Ann. Entomol. Soc. Am. 62:452-453.

Henry, J. E. 1970. Potential microbial control of grasshoppers and locusts. Proc. Int. Study Conf. Current and Future Problems of Acridology, London, 1970. pp. 465-468.

Henry, J. E. 1971. Experimental application of *Nosema locustae* for control of grasshoppers. J. Invertebr. Pathol. 18:389-394.

Henry, J. E. 1972. Epizootiology of infection by *Nosema locustae* Canning (Microsporida: Nosematidae) in grasshoppers. Acrida 1:111-120.

Henry, J. E., and Oma, E. A. 1974. Effects of prolonged storage of spores on field applications of *Nosema locustae* (Microsporida: Nosematidae) against grasshoppers. J. Invertebr. Pathol. 23:371-377.

Henry, J. E., and Oma, E. A. 1980. Protozoa: Pest control by *Nosema Locustae*, a pathogen of grasshoppers and crickets. In *Microbiol Control of Pests and Plant Diseases 1970-1980*. ed. H Burges. Chapt. 30. In press.

Henry, J. E., Oma, E. A., and Onsager, J. A. 1978. Relative effectiveness of ULV spray applications of spores of *Nosema locustae* Canning (Protozoa: Microsporida: Nosematidae) against grasshoppers. J. Econ. Entomol. 71: 629-632.

Henry, J. E., Tiahrt, K., and Oma, E. A. 1973. Importance of timing, spore concentrations, and levels of spore carrier in applications of *Nosema locustae* (Microsporida: Nosematidae) for control grasshoppers. J. Invertebr. Pathol. 21:263-272.

Henry, J. E., and Onsager, J. A. 1981. Results of a large-scale test of the control of grasshoppers with *Nosema locustae* Canning. (In prep.)

Hewitt, G. B. 1977. Review of forage losses caused by rangeland grasshoppers. U.S.D.A. Misc. Publ. #1348. 24 pp.

Menapace, D. M., Sackett, R. R., and Wilson, W. T. 1978. Adult honey bees are not susceptible to infection by Nosema locustae. J. Econ. Entomol. 71:304-306.

Mussgnug, G. L. 1980. Integration of Nosema locustae with chemical insecticides and entomopoxvirus for control grasshoppers. Ph.D. thesis. Montana State University, Bozeman, MT. 115 pp.

Mussgnug, G. L., and Henry, J. E. 1979. Compatibility of malathion and Nosema locustae Canning in Melanoplus sanguinipes (F.). Acrida 8:77-81.

Onsager, J. A., Henry, J. E. and Foster, R. N. 1980. Acceptance of Wheat Bran Bait by Species of Rangeland Grasshoppers. J. Econ. Entomol. 73:548-555.

Onsager, J. A., Henry, J. E., and Foster, R. N. 1981a. A Model for Predicting Efficacy of Carbaryl Bait for Control of Rangeland Grasshoppers. J. Econ. Entomol. (In Press)

Onsager, J. A., Rees, N. E., Henry, J. E. and Foster, R. N. 1981b. Integration of Bait Formulations of Nosema locustae and Carbaryl for Control of Rangeland Grasshoppers. J. Econ. Entomol. (In Press)

Vavra, J., and Maddox, J. V. 1976. Methods in Microsporidiology. In Comparative Pathobiology. Vol. 1. Biology of the Microsporidia. Eds: L. A. Bulla and T. C. Cheng. Plenum Press. New York and London. pp. 281-319.

#1/B

Running head: Control of Grasshoppers by _Nosema_ _locustae_

Indexing words: _Nosema_
microsporida
protozoan
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control
grasshoppers
Acrididae

SOME TAXONOMICAL CONSTRAINTS ABOUT THE USE OF APANTELES sp.

(Hym. Braconidae)

B. SIGWALT - ORSTOM/SENEGAL

The use of Apanteles, group flavipes in the biological control of borers on graminaceous crops shows the necessity of complex preliminary studies. Such constraints are of biological order as they are concerning the taxonomy of the entomophagous species.

At the biological level, the main characteristic of the utilized species, principally A. flavipes Cam. and A. sesamiae Cam is their polyphagous habits. They attack Noctuids (Sesamiae..) as well as Pyralids (Chilo...) caterpillars that are themselves polyphagous on different graminaceous crops : rice, sugar cane, maize, mil, sorgho. Such a crossed polyphagous leads to a high complexity in the field of faunistic inventory that should normally be done before the choice of the entomophagous to be introduced. But the main aspect of that polyphagy is the possibility even probability of the creation of specialized strains (biological strains - sibling - species) on the podential hosts. The results of a given introduction may be in this way different of the original purpose. The alternative generations connected to the polyphagy becomes then a selective mechanism.

As an example, A. flavipes is only found in Mauritius on Chilo sacchariphagus Boj., and Sesamiae a normal host in the original area is not attached. Identically, A. sesamiae in different introductions trials as well as in rearing conditons shows a gradual preference for Chilo although Noctuids are its original hosts.

At the practical level, the use of Apanteles must be done in this way after intensive studies on the possible strains: choice of prospected areas, ecological adaptations , control of the original hosts.

BIOLOGICAL CONTROL OF DATE PALM SCALE IN MAURITANIA

by

Max de MONTAIGNE and FALL Ahmed Maouloud

I. BACKGROUND

1) Coccidiphagous Coccinella (scale-eating ladybugs) and biological control

Coccinellidae feed on a variety of organisms. Most frequently, however, they prey upon Homoptera. These coccinellidae include: aleurodiphages (white fly eaters), aphidiphages (aphid eaters), and coccidiphages (scale eaters).

Results obtained with the latter two groups are often subject to comparison. As a result, it has been found that some of the most successful results in biological control have been obtained with the scale-eating species. Aphid-eaters, though useful, have a more limited effect.

There are several reasons for this:

- Ladybugs (Coccinella) are primarily found in tropical or subtropical zones where winter diapause is either short or non-existent. In simple terms, if they find suitable prey, their yearly development will not be interrupted (in any case, not by climatic factors, even though some estivation has been observed). As a result, several successful cases of biological control of scale using ladybugs have been recorded (not surprisingly) in warmer climates.(1)

Aphids, on the other hand, do their damage primarily in cooler climates where their ladybug predators must go into winter diapause, resulting in higher mortality rates.

- As scales develop continually in these climates, predators have no trouble seeking their prey under whatever conditions suit them.

- Scales are immobile, therefore their predator populations are more stabilized. As these populations are sedentary, usually inhabiting only one plant layer, and as their capability to disperse is somewhat limited, they are not bothered by migrations of their prey (aphids, however, do migrate frequently).

- Aphid-eating ladybugs are often univoltine (reproducing only once a year). Scale-eating ladybugs are polyvoltine, thereby ensuring a development as rapid as that of their prey.

To these differences between aphidiphagous and coccidiphagous ladybugs other favorable, less specific elements may be added.:

-Predator and prey have essentially the same climatic needs;

-the predator's reproductive capacity is high; well superior to that of its prey (ex: ratio of 1 to 100 in the relationship of P. blanchardi/Ch. bipustulatus);

-Belonging to a polyvoltine species, the predator has a more rapid life cycle. Therefore, the number of generations per year is greater;

-larvae and adult predators are voracious (it should be noted, however, that aphid-eating species are more voracious);

-Predators are imported and thus healthy, not carrying parasites or diseases. In general, no natural enemy seriously hinders their activities in their new habitat;

The predator can be:

- EITHER strictly associated with one species of prey, dispersing along with it (Rodolia cardinalis, Cryptognatha nodiceps); on the other hand not completely restricting the scales' geographic distribution, thereby assuring an adequate food supply at least within certain areas;

- OR polyphagous, which is more favorable to the predator's survival, but which necessarily limits its desired impact. This type of predator can eventually find new prey if the primary pest dies out (Lindorus lophantae).

One cannot truly speak of "total pest eradication". Biological control measures are limited, and goals which are sought or attained would be better defined in terms of biological equilibrium. Accordingly, in certain cases (as in Mauritania) where this balance is not yet achieved, it becomes necessary to reinforce predatory activity through the periodic release of coccinellidae.

2) The Case of Mauritania

During the 1960's, at the request of the Mauritanian government, the Institute of Fruit and Citrus Research (I.R.F.A. - ex I.F.A.C.) began research on date palm scale. This scale, several years after its introduction in the late forties, had begun causing severe damage to the new growth of the date palm. The result was a heavy encrusting of the plant surface (rachis, folioles, and dates) which prevented the growth of young tissue and chlorophyllous functions. In addition, trees were weakened by bore holes and the dates became bitter and inedible. Smirnoff (1957) estimated that an average heavily infested tree, ten to fifteen years old, had some 180,000,000 individual scales on it. Their combined effect eventually resulted in death, even for a tree as resistant as the palm.

Research began with studies of pest ecology, of autochthonous (native) beneficial organisms, and of the possibilities of chemical control, which finally led to biological control. The work was carried out in cooperation with INRA (National Agronomical Research Institute) in the Antibes, under the supervision of Mssrs. Benassy, Iperti, and Brun, and was placed under the auspices of the French Committee Against Hunger.

In 1966, an expedition from the Museum of Natural History in Paris, led by Professor Gaillot, left for Iraq and Iran. They brought back a strain of Chilocorus bipustulatus which was slightly different from anything existing in Europe. The strain was thus named the iranensis variety. This variety was reared in quarantine facilities in the Antibes at the same time as other Coccinella (see III) in Mauritania were being tested (but found incapable of adapting).

Beginning in 1967, it became evident that this ladybug was effective and that it had adapted to local conditions despite the presence of an endoparasite, the Protozoan Gregarina katherina WASTON. Scale populations began to diminish.

Mass rearing in-country was thus assured, and releases were carried out in various other areas, such as in Niger. Some trials were even carried out by aerial application via the unique "Lenormand" method.

Presently, the Nouakchott Agricultural Entomology Laboratory (following IFAC's efforts) is using these proven techniques, conducting mass rearing of insects for new releases in all areas where necessary.

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(1) Rodolia (= Novius) cardinalis MULS. against Icerya purchasi MASK. (Margaroidae) in Californian citrus orchards (1888-89)

Cryptognatha nodiceps MAHS. against Aspidiotus destructor S. (Diaspidoidae) polyphagous on various fruit trees of the Fiji Islands (1928-29)

Lindorus (= Rhizodius) lophantae BLAISD. against Aspidiotus destructor in the New Hebrides (1964).

Chilocorus bipustulatus L. var. iranensis against Parlatoria blanchardi TARG. (Diaspidoidae) in the Mauritanian date palm orchards (since 1966).

II I.F.A.C./Mauritania summary of the film, "LADYBUGS IN THE SERVICE OF MAN"

There are two parts to the film:

1) A short, concise introductory part which presents the following:

- The countryside and locale of the palm tree orchards in relation to water systems. There are three important phenicular regions: from North to South, the Adrar, the Tagant, and the Assaba. The Adrar is the oldest and best known region for date palm cultivation. It was there, in Atar, that I.F.A.C. established a phenicular experimentation station.

- Scale in its natural biotope (habitat); the damage it causes and its economic implications.

- Chemical control and its limitations: Emphasis is placed on the ineffectiveness of such a method. Residual effects last no longer than 15 days for parathion, necessitating several treatments. Costs and risks go up accordingly for the contamination of water tables, animals, and of course, man.

The entire presentation points up the necessity for a method more compatible to the environment. Biological control appears to be the answer.

2)a. Preliminary studies

Indegenous predators (not shown in the film) are only moderately active. Therefore, predators originating in other countries (U.S., Iran, Iraq) are imported. The are reared in the Antibes, then shipped to Mauritania, where they are received at the airport in Nouakchott and quickly sent to Atar. It is imperative that the trip be as brief as possible.

Imported ladybugs are separated into two lots:

- one is saved for biological laboratory research (to determine length of cycle, climatic requirements, fecundity, etc).

- the other is placed on a young infested palm tree in the field. The tree is then protected by a large, finely meshed cage (rearing cage).

b. The discovery of an effective predator: Chilocorus bipustulatus var. iranensis.

Ladybugs are periodically taken from the cages and released onto the hearts of diseased trees in selected areas.

Because of the species' voracity and fecundity, rearing cages must be frequently moved. The predators' rapid multiplication quickly results in the elimination of all trace of scales.

Film footage shows the behavior of C. bipustulatus (adult, larvae, nymph, mating and feeding habits). One should especially note the gradual clearing of the tree's greenery and, in comparison, remember the pronounced encrustations at the beginning of the film.

Releases are first carried out in Adrar, then Tagant, and finally around Kiffa and Rosso to the South.

From June to October, hot weather decimates the ladybug population.

This necessitates keeping Coccinella strains in Mauritania and mass-rearing them to renew natural populations when these are thinned-out. A glimpse is taken of the Nouakchott laboratory.

There, in rooms, scales are multiplied using cucurbitaceae (a type of squash) as the food source. These scales are then fed to the ladybugs, who are in turn sent to zones needing treatment (mostly along the borders because of aerial releases carried out in Niger).

III ADDITIONAL NOTES ON EFFORTS TO CONTROL PARLATORIA BLANCHARDI

1 / Parlatoria blanchardi.

The spread of this species is due in part to wind, but is mostly a result of man's activities (marketing of various date palm products, inadvertent conveyance on clothes or in irrigation water, etc). The Middle East and Africa are the principal zones affected, but scale has been carried as far as Australia, South America and the United States.(1)

According to Smirnoff, scale is particularly well-adapted to the hot, dry climate of the Sahara. It thrives in biotopes which are relatively damp and protected against direct sulight (on young plants, at the base of palm trees, on date clumps, and especially in the inner parts of the tree. Very briefly, larval migrations begins at the palm's outer crown and moves toward the center of the tree. Renewal of scale populations corresponds to new growth of the palm (for more details see Laudeho and Benassy 1969).

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(1) In the U.S., Draconian measures taken by the quarantine and inspection services (especially burning) over a thirty year period have resulted in the eradication of scale.

In Mauritania, where the scale's life cycle appears to be largely regulated by temperature, four to six generations, each lasting 45 to 80 days, follow one another in rapid succession without a winter diapause. Fecundity (11 eggs per female) is higher than that observed in Southern Marocco, but is still low for an insect which is capable of such multiplication.

2 / Controlmethods

In addition to the Sultan technique(1) and the burning method(2) chemical control could be considered. However, though this eliminates, or better, prevents scale on young plants before their transport to the field, it is not an ideal solution.

The palm tree is not an easy one to treat using simple means. Good coverage is not always possible, as some parts are covered with fibers or even sand, which shelter the scale.

As previously cited, the lack of the pesticides' residual effects necessitates repeated applications, thereby increasing costs and risks to the environment. The products used (parathion) are not selective as far as insect life, and therefore destroy beneficial insects. None of these methods, then, is truly satisfactory.

3 / Introduction of predators

Some autochtonous insects play a beneficial role. Among these, two exhibit a more lasting presence:

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(1) Radical pruning of young plants, cutting them to the stem (uncertain results).

(2) Rinsing the tree (with gasoline, for example) then passing it over a a flame and finally dipping it in hot salty water (excellent results but high mortality rate in palm trees.

Cybocephalus sp. (Nitidulidae)
Pharoscymnus anchorago F. (Coccinellidae)

Others are less evident:

Chrysopidae, other Pharoscymnus, an Aphelinidae Aphytis mytilaspidis LE BARON, and a few Acariens

In effect, due to a slow rate of multiplication (below their theoretical potential), a reduced lifespan, lack of voracity, and the effects of entomophagous insects and diseases, their impact is insignificant. This makes it necessary to turn to other species.

Iperti, in cooperation with others, has taken the initiative in choosing aphid-eating ladybugs capable of existing in sub-desert climatic conditions, and which both multiply faster and are more voracious than indigenous predators. Trials were thus carried out using four strains:

Pharoscymnus ovoideus SIC of Iranian origin(1)

Chilocorus stigma SAY of U.S. origin(2)found to be too suscept-to Gregarinida

Lindorus lophantae BLAISD did not succeed in adapting, even though its geographic distribution is subtropical

Chilocorus bipustulatus L. var. iranensis of Iranian origin, this strain is at the present time the most effective species and is also best adapted to local conditions (climate, Gregarinida)

a. Rearing techniques

Some particulars are necessary.

Laboratory rearing of Coccinelidae depends first of all on a food source, in this case the Diaspine Chrysomphalus ficus ASHM.

Ch. bipustulatusis not being reared directly on P. blanchardi for the following reasons:

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(1) Ph. ovoideus hamifer SMITH is found at Toungad in the Adrar

- As scales uniquely infest palm species, mass rearing in the laboratory becomes too complicated.

- Ch. ficus, on the other hand, is easier to usc.

- Coccinelidae are somewhat polyphagous. They adapt well to this food source, and once released from the laboratory, switch to the target pest with no problem.

The Cochneal, being a living organism, must have food. Fruits of the gourd family (cucurbitaceae) have been chosen, particularly a Maroccan squash from Zagora which was selected for the following reasons:

- easily stored (times between harvest and use are often variable

Note: Conditions after anticryptogamic treatment - 15° C. 10-20% relative humidity, constant darkness.

- resistant to plant sucking insects. After a relatively long preservation period, the same fruit must be infested and reinfested with several generations of cochneals under conditions which are different from storage.

Note: Rearing conditions of Ch. ficus - 26° C. 40-50% relative humidity, continuous light. Length of cycle one month.

- Easier handling. This cochineal can also be reared on potatoes, which requires more attention (and is not a viable solution for Mauritania).

Coccinellidae introduced into palm orchards must be healthy (not carrying Gregarinida), which makes quarantine important. No cochineal other than Ch. ficus may be allowed to enter the rearing rooms; certainly not P. blanchardi which often carries protozoa.

The ladybugs are raised at 29-30° C. and 40-50% relative humidity having a photoperiod of 18 hours light/6 hours darkness for one month (approx.)

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(2) At Kankossa in the Assaba, the species Ch. distigma KLUG is found. These two species have not produced satisfactory results.

b. Characteristics of Ch. bipustulatus

The species is:

1) polyvoltine: At Adrar it underwent six to eight generations a year without significant slowdown in development. It is, however, susceptible to the very hot temperatures occurring between June and October, which cause estival dormancy or oftentimes a high mortality rate.

2) extremely prolific: The female lays from 750 to over 1200 eggs (5-8 a day) during her life cycle, which averages 60 days but which can last up to four or five months. Under laboratory conditions it takes approximately 35 days to complete the cycle.

3) a voracious predator: a mature larvae or an adult Ch. bipustulatus consumes more than 100 adult P. blanchardi a day/

If one indulges oneself in theoretical calculations, a single couple, sexually mature and producing 8 eggs a day, would have enough successive generations of adults to consume close to 380,000 adult scales within 60 days. This proliferation and voracity have at least two resulting consequences:

- in the laboratory, infested squash must be changed often (depending on the stage of the ladybug, not more than 10-15 days per one hundred predators).

- in palm orchards, ladybugs can quickly control pest populations in certain areas and disappear because of insufficient food supply.

4) found largely at higher levels even though its effects are felt throughout the palm tree.

5) Moderately susceptible to Gregarinida, which attack up to 50%

of population levels. In spite of this, its reproductive capacity can be limited. The effect of high temperatures, particularly in drier areas without shelter from the sun, is definitely disastrous to its survival.

c. Release techniques

The area should be sufficiently infested; adapted, as it were, to the ladybug's voracity.

Favorable release periods are between the end of October and April. Ladybugs can, during that time, colonize the palm trees and disperse ~~their~~ populations.

The Cochineal is more resistant to heat and develops rapidly in the absense of predators (until the ladybug's proliferation permits it to regain the upper hand).

Agricultural techniques must favor the ladybugs:

- sub crops and irrigation, which create a cooler and more humid micro climate, lessening the effects of high temperatures.

- discontinue all burning of straw and dry grass under the palm trees, as this is where ladybugs live

- older palm trees should be cut towards August or September before new activity begins again in October (as a result of prior releases).

(see Tourneur, 1973)

d. Release techniques presently planned. The role of the Nouakchott laboratory.

Once the experimental stage is over and the techniques are perfected, it becomes more sensible to rear ladybugs in-country. The laboratory has gone as far as producing its own Zagora squash (not marketed in

Mauritania) in order to assure greater autonomy.

Air shipments, as one saw in the film, cause little mortality (from 13-16%) despite a series of trips lasting over a week. However, in a more far-reaching operation, it would be more reasonable to set up a special team whose express purpose would be to work on a single Coccinellidae and a single crop (such is not the case at the INRA station in the Antibes).

As in the film, ladybugs will no longer be transported from Atar, but from Nouakchott in all terrain vehicles to the date-producing areas. There, they will be placed on squash infested with scale. For numerous reasons, releases, or rather aerial bombardments, attempted by IFAC have been abandoned. They nevertheless presented the advantages of cutting down distances in a country having few lines of communication. They also permitted simultaneous releases under the required conditions.

Rearing cages are not a necessity, but rather, serve as artificial homes from which quick releases can be made when conditions are right.

Four hundred ladybugs per hectare are necessary (in two releases) to control scale in a palm orchard over a two or three year period. This is equivalent to starting, on the average, with less than two predators per tree.

One can estimate that one ladybug, all expenses included, costs from 200 - 300 UM (1,000 to 1,500 CFA). In comparison, a single treatment of parathion in 1967 cost 50 CFA per tree. Take into account inflation and the multiplying of costs through repetitive applications (and this over two or three years). Compare these factors with the lasting effects of ladybugs, which, in addition, will disperse into untreated areas. Consider the safeguqrding of the environment and the economical and ecological superiority of this control method, and in the end, there can be little discussion.

Apart from technical considerations, the operation's success is also psychological, as there are numerous date-producing nations or international organizations which are aware of the problem.

On the other hand, date farmers have quickly understood the ladybug's beneficial effect despite the fact that some believe they are a universal cure-all. The current match box trade in ladybugs and their disappearances from rearing cages, although disturbing to observers trying to make accurate counts, demonstrate an encouraging attitude on the part of the local populace.

SUMMARY REPORT ON BIOLOGICAL CONTROL OF THE WHITE DATE PALM SCALE (PARLATORIA BLANCHARDI) IN NIGER

Dakar, February 9-13, 1981

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BIOLOGICAL CONTROL OF THE WHITE DATE PALM SCALE IN THE REPUBLIC OF NIGER

I - INTRODUCTION

To the people of Niger, the issue of the white date Palm Scale was obviously not unknown. As early as 1970 all palmtree plantations in the country were widely infested by white scales and damage to date crops was very serious. Under these circumstances preservation of palm tree plantations became a priority task aside from any consideration for immediate profitability.

The National agricultural service was entrusted by the Niger Government to develop phytosanitary techniques which could effectively bring P. Blanchardi under control.

Efforts were undertaken to gathering biological, ecological, climatic and phytosanitary information which were likely to be characteristic of the P. Blanchardi environment. Research activities in the Center for Biological Control were largely directed to obtaining and multiplying this insect in Niger. From 1973 to 1975, it was recorded that the Bio-Control intervention was likely to succeed for the first time as some newly introduced entomophagous species from Mauritania, Chilocorus bipustulatus var. iranensis, had gradually adjusted successfully.

From 1973-74 an implementation program was started in the Aïr and Kaouar areas by using available data and scattering several thousands of scales which were collected from identified natural multiplication locations.

But these multiplication locations which were subject to climatic hazards were inadequate and above all prevented establishment of a program for rational control to achieve wide scale and efficient biological inundation.

An insect facility (Centre operationnel) was constructed in Agadez as early as 1976 for large scale and permanent breeding of Chilicorus bipustulatum .

This publication gives a summary of the achievements and places emphasis on the findings at this Center.

II THE BIOLOGICAL CONTROL APPROACH IN NIGER

This process follows several stages over time :

1. Preparatory stage

The year 1971 and early 1972 were spent selecting areas for insect release, training the needed technical personnel and establishing basic facilities required for implementing the program for introduction of the predator Chilocorus bipustulatus var iranensis.

In the meantime, an upcountry laboratory was being set up in the Agadez area for carrying through the various planned observations: inventory of local predators, research for gregarine sporozoans etc... One plot of land was cleared at Al-Arses and Ingall and cages were installed, covering up palmtree seedlings where the introduced scales were to be multiplied.

2. Implementation Stage

-Inventory of the local entomophagous fauna:

This inventory includes only parasites and predators directly collected from the palmtree plantations for identification.

Following are the species which were observed.

ORDER - FAMILY AND SPECIES	GEOGRAPHICAL DISTRIBUTION
	In all palmtree plantations, a large population at In-Gall.
	In all palmtree plantations
	"
	"
	In all palmtree plantations.
	Al-Arses and In-Gall
	Found in many palmtree plantation but in restricted number.
	Al arses
	In all palmtree plantations
	On Plant Lice;

The main native entomophagous species collected in the Aïr palmtree plantations are Ph. seniglobosus, Ph. Anborago and Cybocephalus sp.

Neuroptera are seen occasionally, but it was only in the In-Gall palmtree paltntations where a fairly large number were observed.

As in Mauritania, the levels of predator and parasite populations were too low to decrease or even limit the increase in cochineal infestations; and therefore it was felt necessary to intervene.

- Research into factors limiting the increase of coccinellids as predators.

Climatology

Palmtree plantations in Niger Aïr are scattered in the numerous valleys of its large mountains. There are no available accurate data on the climate in this area due to the non existence of meteorological stations. Thus, one is asked to extrapolate from Data provided by the Agadez station.

This area has a desert climate, with high temperature averages all year round; very low relative hygrometry and a short rainy season.

The climate chart for Agadez (in figures No. 1 and 2) drawn up according to the method used in the Walter and Lieth World Atlas shows that:

- Very high temperature averages (over 30°C) start in March-April and end in September - October.

Yet these averages are only slightly over 30°C after August;

- The lowest monthly average is 7.6°C.
- Rainfall is fairly high: 158.4 mm.

Some palmtree plantations, mostly referred to as"for picking" are not irrigated , except seedlings. Their growing conditions are not suitable for predator multiplication. In other cases, temporary irrigation is done during the off-season croping period. This results in a slight temperature drop and a rise in moisture. Thus, physical conditions are more favorable than those described in the climate chart (Fig.2) drawn up according to data from the Office National Meteorologique du Niger. The data for the Agadez area are intermediate between those for Atar and Tidjikdja (Tourneur and NDiaye - 1971), which are two towns in Mauritania where the introduced predators expanded steadily. The same process was therefore very likely to take place in Niger.

Search for the Gregarina sp. parasite.

The major natural enemy to many cocinellidae is a sporozon , an intestinal parasite belonging to the genus *Gregarina*. It is the key limiting factor to local predators because of its toxic effect on its host. Though it is known that *Gregarina Katherina*

Watson which is found in Mauritania is not harmful to C. Bipustulatus (Laudeho, Ornières and Iperti - 1969), it was yet interesting to know whether it existed in Niger. Surveys were therefore taken of local coccinellids. The sporozoon was found practically everywhere where Ph. ankocago and Ph. Semiglobosus were collected.

Apparently, there was no forseeable difficulty in carrying out the biocontrol intervention for control of the date palm scale by use of the coccinellid C. bipustulatus var iranensis. Therefore it was introduced.

- Introduction of the chilocorus bipustulatus var iranensis scale.

- Insect transportation.

The coccinellids were flown from, Nouakchott to Agadez. For this purpose small wooden boxes with small drilled ventilation holes obturated with fine bronze linnen grating were used (type used by the Antibes INRA Laboratory - Iperti and Brun - 1969). Each package contained Chrysomphalus fieus Ashm coccinellid infested watermelon. These were used to feed the 2,000 coccinellids to achieve an adequate survival rate during the six day trip. Thus, 4,000 predators were flown over in early 1973 to the areas for release with less than 10% mortality rate.

In cage multiplication

Once the predators arrived in Niger, they were multiplied in cages installed in the Al-Arses palmtree plantation next to Agadez. Each cage (size 2x2x2m) which was made of a tubular frame and wrapped up with a piece of fine nyton muslin covering a highly infested palmtree seedling. A double fabric covered the top of the cage with edges widely sticking out so as to protect it from direct sunlight and lower its internal temperature, which had a tendency to rise due to the muslin wind-break effect.

These three established multiplication units produced an adequate amount of coccinellids for rapid periodic samples to be removed and released in the open air.

Such a structure is still subject to weather related accidents such as cages being stripped away during wind storms. It is also not safe from some disadvantageous situations such as ant and spider attacks.

As this cage coccinellid multiplication was being conducted, direct releases were carried out at the same time in various palmtree plantations in the Aïr from early 1973. Others took place later on (1974) in the Kaouar, Djado and Fachi areas (see special chapter).

Chilocorus bipustulatus var iranensis adjustment.

Before analyzing the various stages of settlement of C. bipustulatus var iranensis in Niger's palmtree plantations and giving a detailed account of its behaviour, chronological summary on the number of insects carried over from Agadez to the various palmtree plantations and names of places where insects were released have to be given.

This data is shown in Table I.

It is interesting to note that out of 22,300 insects which were released in 1973 and 1974, only 4,000 were introduced from Mauritania, which represents over 16,000 insects collected in two tears in the Barbak plot multiplication units at Al-Arses.

A number of insects were taken out and released in order to avoid overpopulation in cages where multiplication was very fast as early as March 1973. This operation could not be continued due to a slowdown in proliferation rate resulting from the early hot season extending from April to mid-July.

As early as August, insects could be released again as multiplication resumed. This period extended through March 14, then was interrupted again during the next hot season. The interruptions in December 1973, January and October 1974 resulted, not from unfavorable climatic conditions or luck of coccinellid proliferation, but simply from a need to carry on further research. Due to distances and limited technical resources, only insect releases in 5 plots at In-Gall and Al-Arses could be followed up regularly.

Table no. gives an accurate account of growth in released insect populations in these plots.

Predators settled down very rapidly as early as May in well irrigated and kept up plots during the first releases in February 1973. A satisfactory coccinellid multiplication was recorded in these plots. Though it slacked off, this proliferation was however sustained during the hot season (May through July). through abundant irrigation of these plots.
As early as August when temperatures drop, insect multiplication and dissemination become intense at Al-Arses. Plots in the vicinity of those where insects were released settled very rapidly. But in late 1973, drought conditions were so serious that a good number of plots were no longer irrigated as a result of wells drying up. Under such conditions, the coccinellids could hardly survive and cirtually disappeared altogether as high temperatures set in.

On the other hand, in plots with regular good care, coccinellid multiplication became significant and their adjustment effective despite the great number of pupae that were t0 be harvested for dissemination in other palm tree plantations.

In December 1974, 20 months after the first introduction, the results were very positive. As a matter of fact, very rapid adjustment and intense proliferation of released coccinellids were recorded in plots where visits and observations were made every month. Findings made in other palmtree plantations point to simiiar results though few observations were carried out. Continued insect presence six months following releases and cleaning up of the palmtree is evidence that results recorded in the Aïr were quite comparable to those priority obtained in Mauritania.

- Dynamics in Chilocorus bipustulatus var. iranensis populatins unfavorable and favorable factors.

Monthly observations for insect presence (larvae and adults) in order to verify predator settlement have led to clear indications on population development over a year's time which we have compared to those of native predators.

This study on this coccinellid's natural behavior in this area where it was newly introduced was carried out in the Al-Arses Barbak plot because of its proximity to the Agadez base.

A linkage was established between periodic ecological surveys of three palmtrees and regional climatic conditions (Fig. 2 a e b)

These curves show a predominance of periods during the year which are favorable to predators . A sharp decline in the latter and populations only occurs durin g the hot season (April through July) and the cold season (January through February).

Shortly after an insect release has been performed, the introduced predators' activities add to the local entomophagous fauna's, but as soon as there is a large number in the former's population, this results in a very significant decline in the latter which sometimes disappear altogether.

Besides temperatures , unfavorable factors include natural coccinellid enemies. A census of these enemies was taken in the Aïr palmtree plantations. The following observations were made.

- hymenoptera such as ants feed on these coccinellids and are sometimes the cause of a very significant mortality rate;
- Praying mantids are sometimes observed in large numbers feeding on coccinellid larvae in places where large populations are recorded;
- spiders to are likely to occur in large numbers. Numerous coccinellid larvae get caught up in their webs.

Under certain conditions, expansion of the entomophagous fauna which is useful to a significant extent may seem to be restrained by combined adverse actions. Nevertheless, a disease caused some Gregarina sporozoon is still the most significant danger. Thus, regular dissections were carried out to follow in the percent increase of infected populations during the year. the findings are given in Table 3.

This table shows that parasite rates recorded for C. bipustulatus are still very low. They seldom exceed 10%. They are much higher (up to 70%) for Pharoscrymnus sp. which can account for this coccinellid·lack of efficiency.

To date, this disease has not prevented intense multiplication of C. bipustulatus wherever climatic conditions are not a limiting factor.

Analysis of Control efficiency of the bio-ecological intervention

From the results obtained over the two years intervention we can now show the predator efficiency of the introduced coccinellids and assess improvement in the conditions of palmtree plantations.

By way of 0 to 5 grade system (Tourneur and Vilardebo - 1975) assigned according to scale infestation levels of each of the three palmtree areas, one can find an average level of palmtree infestation. With repetition of this exercise overtime, increases in infestation intensity can be followed up, as well as infestation decline resulting from the predator's effect. The o0 grade corresponds to total absence of scales, while 5 represents total scale infestation.

Expansion of P. Blanchardi populations during the year .

Knowledge of the host was essential to adequately carry the operation through.

This type of development was followed up in the Sadeck Landsary plot at In Gall where there was no distrubance resulting from a low coccinellid increase (Fig. 3).

Two maximal levels were observed each year. Depending upon the years, the highest occurs between April and June and the other maximal level which is quite a bit lower takes place between October and December. As the high Summer temperatures set in, a significant decline to a minimal level in P. Blanchardi populations was recorded between July and sometimes up to October.

Predator efficiency of C. bipustulatus var iranensis.

The predator efficiency was enhanced in the Barback plot at Alarses (fig.4). As this plot had received permanent and adequate irrigation for its off-season Winter vegetable and cereal production and its Summer forage crops, there was intense multiplication of the introduced predator populations as a result of permanent favorable conditions.

Throughout 1973, there was a steady decline in the infestation level. This regression is more noticable in August when infestation usually tended to increase. This peculiar development results from predatory action by coccinellids released in July. High population can be observed in June, but the high heat leads to temporary regression (July-August).

In spite of this, 75% to 80% of palmtrees are hosts to sizeable reproductive populations (Fig. 4 a). As a result, there is minimal infestation (0.5 grade) in December. The cool season, lack of food and return of high April temperatures resulted in a significant decline in coccinellid populations and increase in scales, but as early as June, predator multiplication was very intense again. All palmtrees are at this time hosts to a large number of coccinellids which immediately results in a rapid infestation drop to 0.5.

This predator efficiency is connected to the existence or creation of Summer refuge areas (Tourneur and Huges - 1975).

As a matter of fact, these areas have never existed in the In-Gall Landsary plot, and despite two consecutive insect releases in two years, the predator populations have not developed and no drop in infestation level has been recorded (fig.3).

4 RELEASE EXTENSION TO THE TABELOT AREA.

Locations where coccinellids were released are recorded in table I. In most cases, settlement was successful as can be seen by species' presence and improvement in palmtree conditions several months later. All these places are located East of the Aïr. From early 1974, with the World Church Service Financial assistance, establishment of a small facility enabled extension to the East of the mountains.

The first task was a census of palmtree plantations and grading of their infestation levels existence of off-season crops etc..... A palmtree plantation located near the Tarbelot village was rented in order to carry on periodic observations.

The first coccinellids were released in this palmtree plantation in August 1974. Other releases followed at Tekaref, all along the boris at Telewass, Afassas, Abardack and Nabaro, as well as in palmtree plantations located on Mount Bagzans.

As early as October, all palmtrees were inhabited by Coccinellids i n the Tabelot plot. A large number had migrated to neighbouring palmtrees, and their action was already manifest. Due to the long distance to the Easter sector, and difficult access to some palmtree plantations, permanent control of the change in coccinellid populations could not be achieved. However, it can be said that this was a reflection of what was noticed elsewhere, that is rapid and immediate multiplication in some sectors while the predators could only barely survive in others.

5) EXTENSION OF THE BIOCONTROL INTERVENTION TO THE KAOUAR, DJADO AND FACHI AREA.

After coccinellid releases in the eastern palmtree plantations of the Great mountains of l'AIR, only one sector was left uncovered by the biological control operations. This sector area included palmtree plantations located beyond the Ténéré Desert, the Kaouar, Djado and Fachi areas.

Preparation for this extension was the purpose of a field trip from March 6 to 26, 1974. The need for general and specific data collected on palmtree plantations in this area, and particularly on their infestation level by the P. blanchardi scale, made such an inquiry absolutely necessary. At the same time, a survey was undertaken of the agronomic activity in this area.

The figures which have been recorded indicate a very significant decline in palmtree numbers for the past 20 years. Causes for the decline of date-palm farming include, among other things, the loss of human population in these areas completely isolated by 606 km of continuous desert in addition to the drought throughout the Sahel which, by contributing to a gradual decline in millet, sorghum and other food crops, prevented thousands of camels from transporting these goods which were destined for exchange with dates.

Sustained date production is therefore vital to these areas, not only as it is practically the unique source of wealth in this country, but also because without the shade of a date palm, no form of agricultural production is possible and as a result, no form of human life could be sustained.

These are the reasons for this field survey. Virtually, all Blima palmtree plantations at Djado as well as Fachi's were visited. Parlatoria blanchardi infestations were observed and recorded. This pest is everywhere, but on the whole in small to very small numbers, except sometimes in localized areas.

At the end of the field survey it could be concluded that pest levels were rarely reached and that there was no need for a bio-ecological intervention.

Yet 2,000 coccinellids were transported including a thoushand from the Nouakchott quarantine facility and another thousand from breeding at Agadez.

These insects were released to a few palmtrees where infestation levels were highest. These include the BILMA, Chemidour, Dirkou, Achemoua, Seguedine and Fachi palm plantations.

These insects will not probably survive for a long time as conditions are not favorable, except at bilma and chemidour where various off season crops are sustained due to an abundant water supply. It is expected that these scales cannot settle permanently in these areas, as very low infestation levels will prevent an adequate multiplication rate.

6) FINDINGS

Following completion of four years of research work in Niger, what can we conclude?

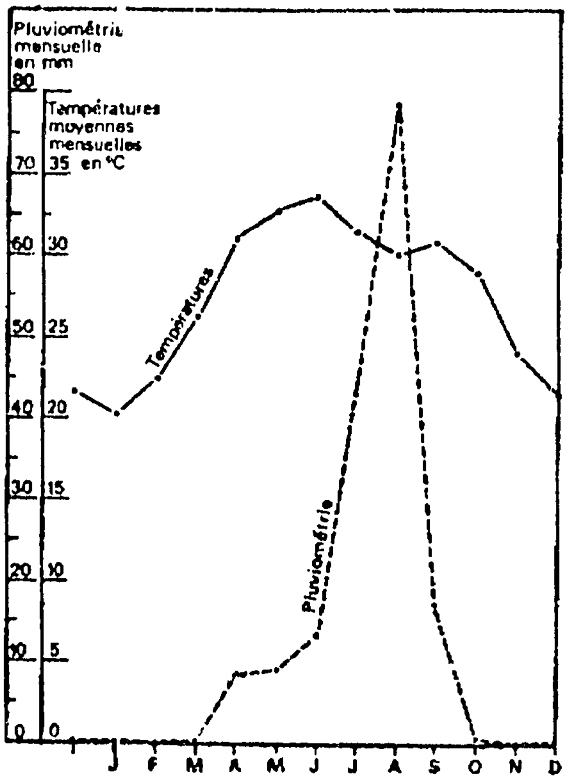
Although there is a marked slowdown of activity at a certain period in the year; Ch. bipustulatus var. iranensis outlines the harsh conditions of the hot season. It can be stated now that its introduction and adjustment have been fully successful in the In-Gall and Aïr areas, as was already the case at Bilma in the Kaouar, Djado and Fachi areas.

Wherever the coccinellid survives there is a tremendous drop in the scale infestation level with a continuing decline.

Up to date, we must not raise any expectations for complete eradication of this pest, but the predator efficiency is such that where Summer refuge areas are created and maintained, this reduces the phytophagous population to a level close to 0.5. This new host-predator equilibrium seems to be stable. In some palmtree plantations of Niger's Aïr, this balance has been maintained for eight years.

On the other hand, if the Summer refuge areas are not maintained after improvement of the plot with C. bipustulatus var. iranensis, there could be a rapid development in the scale population, as soon as the predators disappear.

In order to confront such a possibility, one or two abundantly irrigated plots have to be maintained where the coccinellids could survive and multiply every year. The necessary material must be provided if by chance, pest expansion and lack of the introduced predator required another biocontrol intervention.



AGADÈS

Altitude (m)	500
Nombre d'années d'observation	13
Température moyenne annuelle (°C)	27,8
Moyenne des températures minimales journalières du mois le plus froid (°C)	7,6
Température minimum absolue (°C)	4,2
Moyenne des températures maximales journalières du mois le plus chaud (°C)	42,5
Température maximum absolue (°C)	45,3
Pluviométrie moyenne annuelle (mm)	156,4

FIG. 1 • CLIMADIAGRAMME D'AGADÈS ÉTABLI SUR TREIZE ANS, DE 1958 À 1970.

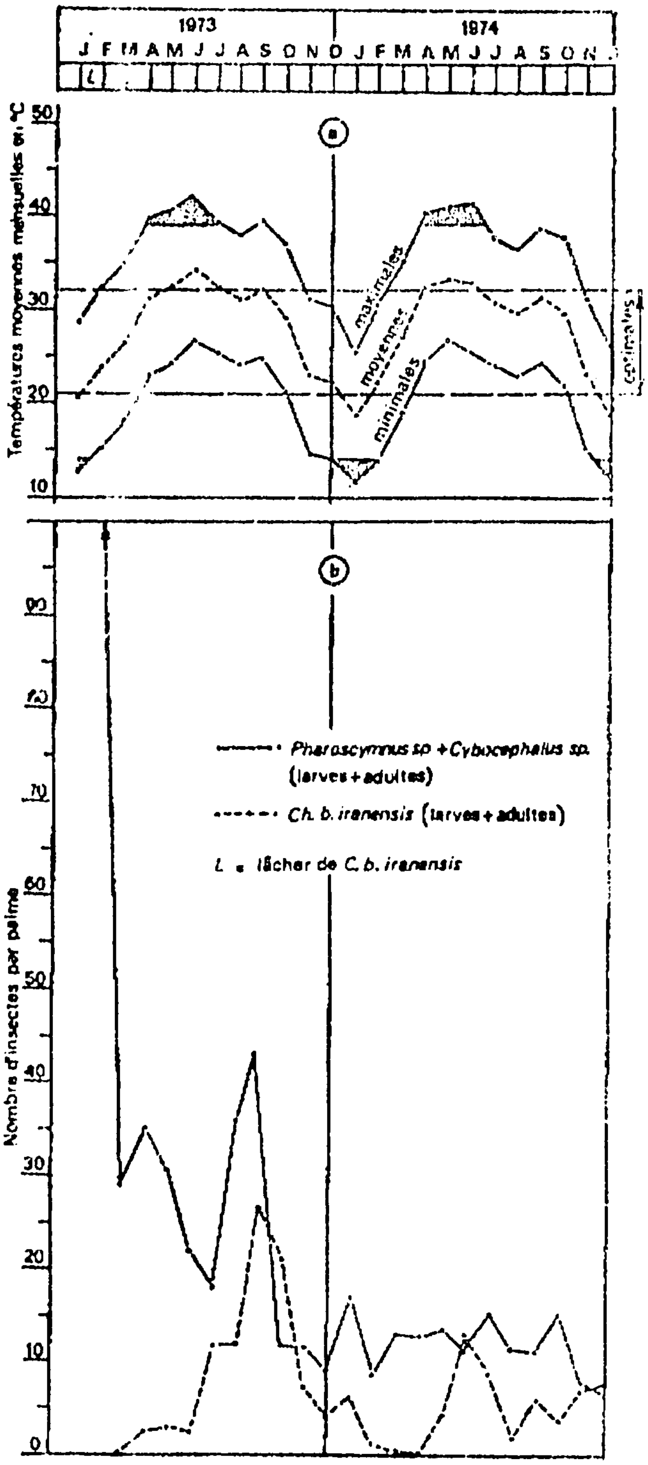


FIG. 2 • ACTIVITÉ DE *CH. B. IRANENSIS* COMPARÉE À CELLE DES PRÉDATEURS INDIGÈNES À AGADÈS.

TABLEAU n° 2

Evolution de l'acclimatation de C. bipustulatus var. iranensis, dans quelques points de lâchers suivis régulièrement dans l'Aïr nigérien.

Palmeraies	1973											
	J	F	M	A	M	J	J	A	S	O	N	D
PALMERAIE D'AGADES												
Parcelles :												
Barbeck		L	P	P	↗	↗	↘	→	↗	↘	↗	↗
Langoussoum							P	↗	↗	↗	↗	↘
F.A.N							P	↗	↗	↘	P	P
PALMERAIE D'IN GALL												
Parcelles :												
Sadeck Landcary		L'	P	P	↗	↘	↘	↗	↘	D	L	↗
Ali Landsary		L	P	P	↗	↗	→	↗	↘	D	L	↗

L: Lâcher d'adultes de C. bipustulatus var iranensis
P: Présence de " "
D: Disparition de " "

Maintien, augmentation et diminution de la population de C. bipustulatus var. iranensis

TABLEAU n° 3

Evolution de l'acclimatation de C. bipustulatus var. iranensis, dans quelques points de lâchers suivis régulièrement dans l'Aïr nigérien.

Palmeraies	1974											
	J	F	M	A	M	J	J	A	S	O	N	D
PALMERAIE D'AGADES Parcelles :												
Barbeck	↘	↗	↘	↘	→	↗	↗	↗	↗	↗	↘	↘
Langoussoum	→	→	↗	→	↘	P	↗	↗	↗	↘	↘	↘
F.A.N	P	P	D									
PALMERAIE D'IN GALL Parcelles :												
Sadeck Landeury	↗	P	P	P	P	P	P	D				L
Ali Landsary	↗	↘	P	P	P	P	P	↗	↗	↘	↘	D

L: Lâcher d'adultes de C. bipustulatus var iranensis
P: Présence de " "
D: Disparition de " "

Maintien, augmentation, et diminution de la population de C. bipustulatus var. iranensis

TABLEAU n° 4

Pourcentage de coccinelles adultes parasitées par *Gregarina* sp.

Coccinellidae observés	Décembre 1973 et Janvier-Février 1974	Mai 1974	Août 1974	Novembre 1974
Chilocorus bipustulatus var. *iranensis*	05	05	10	15
Pharoscymnus anchorago + *Ph. semiglobosus*	69	45	30	45
156 individus au total (répartis ainsi)	36	40	40	40

FIG. 5 • EFFICACITÉ PRÉDATRICE DE *CH. B. IRANENSIS*.
ASSAINISSEMENT DE LA PARCELLE BARBECK
À AGADÈS-AL ARSÈS.

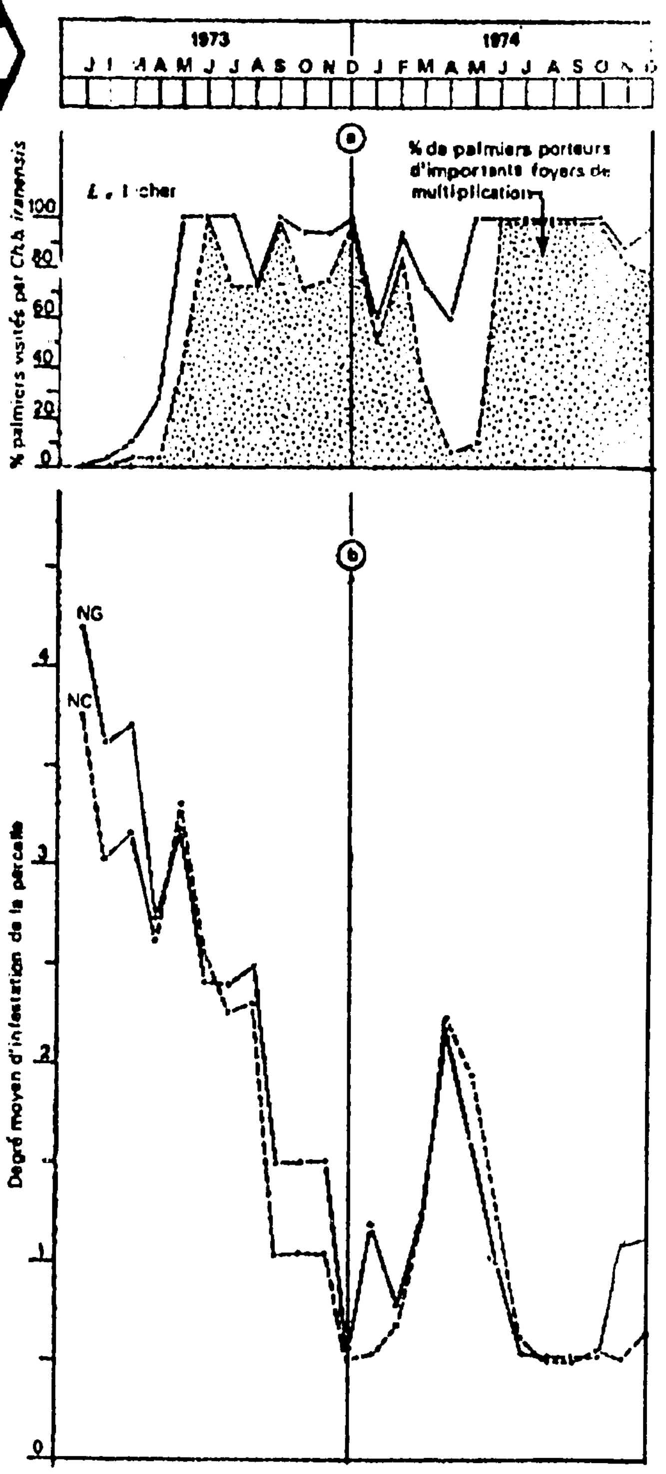
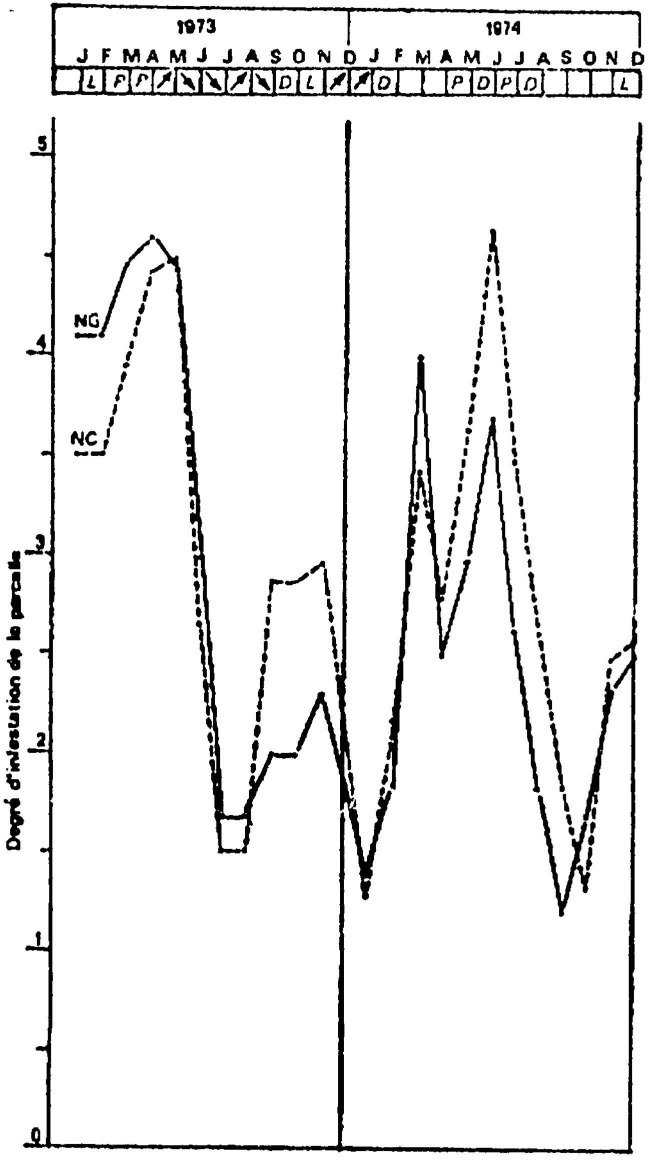


FIG. 4 • ÉVOLUTION DES POPULATIONS DE *PARLATORIA BLANCHARDI* À IN GALL. PARCELLE SADECK LANDSARY.

Population de P. blanchardi :
NG = note générale NC = note du coeur

Population de Ch. b. iranensis :
L = lâcher *P* = présence *D* = disparition
↗ augmentation → maintien ↘ diminution



Nombre de Chilocorus bipustulatus iranensis adultes lâchés
dans les diverses palmeraies de l'Aïr, du Kaouar et de Djado, au Niger
(Chronologie des interventions)

Palmeraies	1973													1974											
	J	F	M	A	M	J	J	A	S	O	N	D	J	J	F	M	A	M	J	J	A	S	O	N	D
	Chilocorus bipustulatus iranensis non encore introduite.	Introduction en provenance de Mauritanie				Pas de lâcher							Pas de lâcher			Introduction en provenance de Mauritanie			Pas de lâcher				Pas de lâcher		
Agades (Al Arnes)		1.400																							
In Gall		2.600									400														6.100
Tabelot			450						400						115										
Irwalen								450																	
Tassalamsalam									100																
Amati										200															
Tadeliza										250														1.000	500
Tifotikin										400															1.000
Maghas															100										
Isinabaro															250										
Ilialan															55									250	
Tchibizgan															60										
Ahrakh															30										
Tistaiza															65										
Tagalet															55							250			
Birni															10										
Takaraif															25										
E B U															60										
Kwawila (Bagzane)															25						50			100	
Elmolcoli															20										
Ighalghaban															15						50			150	
Bilma (tomaro)																600									
Dirkou (fan)																70									
Chemidour																60									
Achenouma																1.100									
Aney																100									
Seguedine																100									
Djado																100									
Fachi																80									
Tadibargot															105						250				
Azzaf																								300	
Edodo																								250	
Alazza : golo																								300	
Inchigidale																								1.000	
Aljima																								300	
Nabaro																								300	
Akaki																								200	
Talawag																								[illegible]	
Totaux		4000	450					450	500	850	400				290	2.290					350	250		5250	7700

Kaouar et Djado

215 F

soit au total global de 22.300 insectes lâchers dont 6.000 introduits de Mauritanie.

STRATEGIES IN THE CONTROL OF THE PRINCIPAL PESTS OF CAPE VERDE

CARLOS BRITO

Having considered the geographic isolation, the distance between the islands of the archipelago, and especially the fragility of the agrosystem due to drastic variation in landform and rainfall, the Crop Protection Department of the Ministry of Rural Development has developed a plan of Integrated Pest Management. Several international organizations (GTZ, FAO, USAID, ORSTOM, etc.) have joined us in an effort to substantially increase basic food production, without pollutting the environment in which live more than 295,000 Cape Verdians.

The following measure are planned, or are already in practice.

1. Biological Control Measures. The principal agricultural pests in Cape Verde have been introduced without their natural enemies. Parasites and predators presently found attacking pests in Cape Verde crops are presented in Table I. The following pests were given priority in programs of new releases or population management.

a. Cabbage Moth (Plutella xylostella). A three year contract was signed with Commonwealth Institute of Biological Control in which CICB will provide parasites such as Apanteles plutellae and Tetrastichus sokolowskii, as well as train senior staff in methods of biological manipulation. The Crop Protection Department also has strong interest in introducing Apanteles litae operculellae from Senegal where up to 50% parasitism of cabbage moth have been observed in the months of April and May (L. Bourdouxhe, Camberene Horticultural station). Formulations of Bacillus thuringiensis show promise in controlling this pest, especially when used as a complement to the action of parasites, and due to its use against larvae of other lepidopterous species.

2. Integrated Control Measures. The general orientation of the Palnt Protection Service is guided towards the development of an integrated control problems scheme of the following major pests.

a. Grasshoppers, including Oedalus senegalensis, Catantops auxillaris, Pseudosphingonatus savignyi. Bioecological studies of these species will permit improvement in the present control methods, which include toxic baits and insecticidal formulations.

b. Sweet potato weevil, Cylas puncticollis. We hope to increase yield per hectare by putting into practice good cultivation methods (agricultural hygiène, disinfestation of reproductive material), and finding pest resistant varieties.

c. The fruit fly, Dacus frontalis. An intensive work plan has been developed to study the distribution,biology, ecology, and population dynamics of the pest, as well as the agronomy of its most important host, Curcubita pepo with the goal of generically controlling this pest problem.

d. White fly, Bemisia tabaci. This aleurodid, as the vector of tomato yellow leaf curl virus (T Y L C V) has caused enormous losses in the tomato crop. Satisfactory results have been obtained by mechanical measures to protect the seedlings, strict application of pesticides during the first weeks of growth, improved cultural practices; all in conjunction with the use of resistant varieties.

e. Millipedes, Spinotarsus sp. This prolific pest, only recently introduced into the island of Santo Antao has become a devasting pest on tubers of English Potatoes, sweet potatoes, young cassava, and ripe fruit when in contact with the soil. Cultural hygiène, treatment of the seeds with insecticidal dusts. and toxic baits have succeeded in reducing the problem.

ENTOMOPHAGE FAMILY	HOST/PREY	HOST PLANT
1. Aphytis diaspidis (Aphelinidae)	Aonidiomytilus albus (homoptera)	Cassava, Acacia (Parkinsonia aculeata)
2. Arrenophagus chionaspidis (Aphelinidae)	Pinnaspis strachani (homoptera)	Cassava, Congo Bean
3. Encarsia tricolor (Aphelinidae)	Bemisia tabaci (homoptera)	Tomato, Bean Cuncumber, Tobacco, Unkrauter
4. Eretmocerus mundus (Aphelinidae)	B. tabaci	" "
5. Coccophagus rusti (Aphelinidae)	Saissetia sp.	Weinrebe grapevines (Santo Antao)
6. Prospalltella sp (Aphelinidae)	"	"
7. Habrolepis opugnatii	"	"
8. Stenomesius japonicus (Branconidae)	Cosmopterix sp. (Lepidoptera)	Beans, Dolichos
9. Lysiphlebus sp. (Braconidae)	Brevicoryne brassicae (Homoptera)	Kohnlarten
10. Diaretiella rapae	"	"
11. Trissolcus basalis	Nezara viridula (Heteroptera)	Maize, Beans, Acacia
12. Bracon sp. (Braconidae)	Etiella zinckenella (Lepidoptera)	Congo Beans, (C. cajan).
13. Coccinella 7-punctata (Coccinellidae)	Aphis craccivora	Dolichos lablab
14. Rodolia cardinalis (Coccinellidae)	Icerya purchasi	Congo Beans , Citrus

15.	Chilocorus nigritus	Cocus viridis	Citrus, Coffee
16.	Pharoseymnus exiguus (Coccinellidae)	A. albus	Cassava
17.	Soymnus posticus (coccinellidae)	Aphidoidea	Maize, Beans, w.w.
18.	Cybocephalus nitens (Nitidulidae)	A. albus	Cassava
19.	Ischiodon aegypticum (Syrphidae)	Aphidoidea	Maize, Beans, Kohlarten
20.	Chrysopa plagata (Chrysopidae)	Coccus spp., Aphidoidea	Citrus
21.	Polistes sp. (Vespidae)	Chrysodeixis chalcites	Kohlarten
22.	Feltiella sp. (Cecidomyiidae)	Tetranychus spp.	Beans
23.	Exochomus nigripennis (Coccinellidae)	Coccus viridis	Coffee, Citrus
24.	Nematoscelis filipes Woll.	Tetranychus spp.	Cassava
25.	Amblyseius fallacis (Phyteseidae)	Tetranychus cinnabarinus, T. urticae	Congo Bean, Bean
26.	Iphiseius degenerans (Aoarina)	Tetranychus spp.	Papaya
27.	N.N. (Einerasit, Hymenoptera	Papilio demococus	Citrus
28.	N.N. 1 (Hymenoptera)	Coccus hesperidum	Citrus (Orange)
29.	N.N. 2 (" ")	"	"
30.	N.N. 1 (Lepidoptera)	Coccus viridis	Citrus, Coffee

31.	N.N. (Stephilimidae)	T. Cinnabarinus	Beans
32.	N.N. (Formecidae)	Plutella xylostella	Weibkhol
33.	Cephalosporium lecanii (Deateromycate)	Coccus viridis	Coffee, Citrus
34.	Halcyon leucocephala (Nauberlacher Vogel)	Oedaleus senegalensis, C. chalcitae; Kleine Mause	

Presentation given during the "International Conference on Biological Control and Its Potential in West Africa".

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The possibilities of Biological Control against Plant Parasitic Nematodes in West Africa.

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I. INTRODUCTION

As an introduction to this paper, it would seem necessary on the one hand, to expand the definition of biological control, and, on the other, within the context of this meeting, which is largely concerned with insect pests, to remind ourselves of the economic importance of plant parasitic nematodes in West Africa.

- Biological Control: For some time the meaning of this term has been restricted to methods using parasitoids, which is not implicit in the two words that make up the term. With regard to a larger definition, Biological Control becomes a composite of methods having to do with biologically protecting the host by attacking the parasite. These methods are divided into three groups according to whether they concern the biology of the parasite, the host, or a third organism.

- Plant Parasitic Nematodes:Microscopic in size, living in the soil, affecting the host plant at the root, the plant parasitic nematodes are understandably less understood by the farmer than the insects which attack plant parts above ground. Furthermore the infested plant, except for the rare exception of galls, does not show any specific symptoms. The presence of nematodes cannot therefore be detected except by analysis of soil samples and roots conducted in a specialized laboratory.

In Senegal, Ivory Coast and Upper Volta, the chemical denematisation of soils allows the doubling of yields in certain crops such as peanuts, soya, several vegetable varieties and feed corn. This substantially adds to the yield of irrigated rice and sugar cane. At this time, we do not have statistics concerning the economic impact of Nematodes in other West African countries. The information presented in this report comes essentially from the work done since 1955 by the Department of Nematology at ORSTOM which has one laboratory in DAKAR and another in the Ivory Coast.

II. CONTROL METHODS HAVING TO DO WITH THE BIOLOGY OF NEMATODES:

The principle method is that of clear ground fallow based on two biological properties of plant parasitic Nematodes:

- The longevity of infested stages is limited to a few weeks by the quantity of reserve nutrients necessary for metabolism.

- These organisms, strickly plant parasitic, can only renew their reserves or continue their life cycle, on a living plant, whether its usual host or an alternative.

Advantages: This method is very efficient for certain nematodes such as *Scutellonema cavenessi* a parasite of peanuts in Senegal.
The cost corresponds to that of a laborer or the price of the necessary amount of herbicide. The fallow period is part of the recommendations already considered by ISRA for the peanut growing areas, it suffices only to add to this the activity of ground clearing.

Disadvantages: This method is only efficient if one is sure that the soil does not harbor roots of neighboring perennial plants that act as a reserve for nematodes. (as in the case of wind break trees for the nematode genus *Meloidogyne*:parasites of vegetables); also if the current ecological conditions do not induce a reduction in the activity of the Nematode, which suspends it's metabolic activity to prolong its survival (diapause).

Moreover, in the rural sector, it could be difficult to introduce ground clearing of a field that will only be planted again the following year.

Another method is under study in Dakar, based on the attraction which roots of the host plants have on the plant parasitic nematode. At this time, our efforts are directed to precisely determining this attraction in such a way that one could disrupt it by methods which remain to be specified.

III. CONTROL METHODS HAVING TO DO WITH THE BIOLOGY OF THE HOST PLANT:

The principle method consists of using resistant plants. In the case of nematodes, feeding on the host plant roots is conducted in a simple fashion such as by sucking out the cellular contents, or by a method more complex, such as injecting a saliva which transforms the contents of several cells contiguous to the root. The product of this extracellular digestion is then absorbed. In certain cases the adaptation is perfect. There is nutrition and development of the parasite: the plant is susceptible. In other cases, incompatibility becomes evident, the nematode not being able to be nourished , dies: the plant is resistant.

Varietal selection is one of the more elegant methods of controlling Nematode problems of the genus Meloidogyne, a parasite of vegetables. Among the recognized biochemical mechanisms of this resistance, note should be taken of the presence, in the saliva of the Nematode, of a hydrolase enzyme, and in the cells of the resistant host, a glycoside. The hydrolase breaks down the glycoside, releasing a toxic product that kills the plant cell and the Nematode.

Resistant plants can either be producers (Rossol tomatoes resistant to Meloidogyne) or are used as "trap plants" allowing the cleaning up of a plot (as in the case of peanuts for Meloidogyne used as green fertilizer).

The advantages of this method are considerable, but they nevertheless present some problems:

- certain races of Nematodes appear, especially after prolonged use of resistant varieties, which are capable of developing on these plants: it is thus said that the resistance is broken. These races of Nematodes are called race B. With regard to the mechanism of resistance referred to above the B race corresponds to a mutant which no longer produces hydrolase.

-certain resistant varieties selected in temperate countries become susceptible when they are introduced into a tropical climate.

- for certain crops it has not been possible to find varieties resistant to their principle nematode parasites (as in the case of rice and nematodes of the genus Hirschmanniella).

IV. METHODS HAVING TO DO WITH THE BIOLOGY OF A THIRD ORGANISM.

- Predators and Parasites: Soil fungi of the genus Arthrobotrys are capable, with the aid of specialized cells in the form of a ring, to attract, capture, kill and then digest the infective stage of nematodes such as Meloidogyne. In addition, these same nematodes are susceptible to infection by an internal parasite, Bacillus penetrans which renders them incapable of reproduction. During a study effected in the primary vegetable growing area of the region of Dakar, these two organisms were found in the greater part of the samples, but were not inhibiting the infestation of these soils by Meloidogyne. Their activity is therefore insufficient. In Senegal, the introduction of a predatory fungus on nematodes, commercially produced with success in France, has come up against a block: the fungus does not seem capable of surviving to establish itself in the soil. In this case one can reasonably point to a lack of adaptation to local ecological conditions vis-à-vis an organism selected in temperate zones: temperature, PH and content of organic matter.

- Symbionts: Very recently researchers have indicated that innoculation of tomato and cotton roots by mycorhize diminishes considerably the penetration of these roots by nematodes of the genus Rotylenchulus.

- Sulphur - reducing bacteria: certain anaerobic bacteria of the genus Desulfovibrio present in the soil of unundated rice in Senegal and Ivory Coast produce soluble sulphur which is toxic to parasitic nematodes of rice, genus Hirschmanniella. This production could be raised by the judicious addition of sulphur fertilizers. This sulphur also being toxic to rice, it would do well to undertake the operation between cropping seasons.

However, a good control of water is indispensable to recover the rice fields after this operation. A program for practical extension methods is under study at the Dakar soil science lab.

- Toxic plants: The roots of Targetes patula ("eye of India") excretes in the soil substances toxic to Nematodes; apparently a type of mustard gas. It suffices to include these plants in a seasonal crop rotation.
Certain parts of the Neem tree (Azadirachta indica) contain the principle parts of a nematicide, especially the leaves and fruit.
Their incorporation into the soil seems to permit according to researchers in India and Nigeria a diminuation of soil nematode populations.
Preliminary experiments on this subject are under study in Senegal.

V. CONCLUSION

Efficiency: Methods of biological control against nematodes are sufficient by themselves (resistant plants; rotation) or they can serve to reduce reinfestations after chemical treatment. In the latter case they serve to deminish the financial costs of chemical treatment.

Application: The principle difficulty of these methods resides in their introduction into the practical agricultural methods of the farmer. However, one can count upon the attractive aspect of their small cost. The introduction will without doubt be facilitated if the extension agents are able to acquire a more complete understanding of the various constraints to these crops: Nematodes and others.

OTHER PATHOGENS IN THE SOIL: That which was spoken of for Nematodes with regard to biological control will have little relevance for other soil pathogenic organisms (bacteria, virus and fungi). It would seem desirable that the first action involved in an integrated control approach would be to identify the entire complex of pathogenic agents that threaten a particular crop.

Stepping Stones to Success

by

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For presentation at the USAID-SAHEL Food Crop Protection Project -

International Conference on Biological Control of Pests, Its

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Stepping Stones to Success

When I was first given the title for this address, I considered it to be somewhat presumptive. However, on second thought I realized it was not presumptive at all. The past record of biological control has shown that if we follow certain stepping stones, success will follow, although not always to the degree we had expected.

With the ever-increasing international shipment of agricultural products, rapid air transport between countries, increasing tourism, and the general opening of frontiers throughout the world, the danger of introducing an exotic pest into a new region is staggering. Facilities for intercepting pests are often insufficient, due to financial restrictions or shortage of trained manpower, or they may be nonexistent. Furthermore, even the most stringent restrictions are not much more than a delaying process if neighboring countries do not have similar restrictions. Political borders are no deterrent to pest invasions.

These invasions, coupled with the ever-increasing demands upon our food and fiber sources, require that the pests be controlled successfully within the financial limitations of the society involved. This is not new information for all of you. You have been faced with this problem for years, and you know, all too well, that the solution is not easy. It is an enormous task just to keep the food supply increasing as the population increases. Yet we must. Somehow, there must be food available for those people who work so hard and yet demand so little.

This Conference has as its title "Biological Control of Pests, Its Potential in West Africa." During the past few days we have examined, in detail, programs from different parts of the world. Also, we have looked at the international web of laboratories throughout the world that are devoted to research in biological control. There have been, I believe, enough successful examples of biological control to warrant a serious consideration of the method of pest control and how it may be utilized in West Africa.

Now we will examine the steps to be followed to establish a biological control project. When an organism is recognized as a pest species, what is to be done to control it by using natural enemies?

There is a series of steps or procedures to be followed to establish a biological control program directed against a specific pest. These will vary somewhat depending upon the species of pest, what is known about the pest and its associated natural enemies, the extent of research done with the pest in neighboring countries or other parts of the world, and the limitations in manpower and funds available.

1. Identification of the pest. This is an essential part of any research program in biological control. Everything that follows is dependent upon the accuracy of the identification. Incorrect identifications can cause losses in time and funds and may lead to surveys in the wrong part of the world. For example, I spent several months in Iran working on a plant we believed to be in one genus when actually it had been misidentified. The genus did not occur in Iran. As a result, we had to move our research to Morocco where the genus was known to occur. However, by that time we had already expended a considerable amount of time, energy, and funds.

We cannot over emphasize the need for accurate identification of the pest species during the initial stages of a project. Later, as natural enemies are uncovered during the project, their accurate identification also will be essential.

2. Compilation and evaluation of preliminary information and planning.

a. Geographic distribution of pest species. It is necessary to determine the origin of the target organism, or at least determine the distribution of the genus to which it belongs. This information often can be obtained from taxonomic specialists in the group through a search of the literature, by examining museum specimens, or from information on trade routes, by examining the distribution of the host plant itself, and from climatic information.

b. Resolution of any conflict of interest. Occasionally, an organism will be considered as a pest species by some and as a useful species by others. This is not uncommon when a plant is being considered as a target of a biological control project. For example, some rangeland plants are considered as pests to the cattle industry because of their toxic properties. However, these same plants may be of considerable importance to the honey industry as a source of food for bees and to wildlife people for their value to animals and birds. These conflicts must be settled, possibly by monetary compensation or through changes in cropping practices. Sometimes, the fears of conflict are groundless--other times, they are real and may present a serious obstacle to a particular project. How this is solved will depend upon the laws and customs of the country where the question arises.

c. Location of potential sources of desired natural enemies. Through contact with individual scientists, research laboratories, universities, and governmental agencies, an adequte supply of the desired organism may be obtained. This would eliminate the need for foreign exploration, screening, and most of the steps prior to release and evaluation. This information may be obtained by contacting major research laboratories, organizations such as the Commonwealth Institute of Biological Control, INRA, IITA, and other tropical institutes, as well as specialists in the specific field of research.

d. Evaluation of the possibility of control by natural enemies. In my opinion, this evaluation should be practiced more often and in more detail in the field of biological control. There has been more effort to do this when considering projects for the control of weeds than has been done for projects concerned with arthropod pests. An evaluation is essential before embarking upon a project. Because biological control projects are usually long-term, it must be determined if adequate finances will be available to support a project for a long period--often 8-10 years or even more. Also, will the current control practices for other pests negate the benefits derived from an introduced organism? It is useless to introduce a beneficial insect against one pest if a spray program directed against a second pest will eliminate the beneficial or reduce its effectiveness.

Another factor to consider is the level of damage that will be acceptable when evaluating the success of a particular project. For example, a pest population in a forage crop such as alfalfa does not need to be reduced to a very low level for a project to be considered successful. This type of crop can withstand considerable damage and the yield will still be economically acceptable. However, the population of a pest attacking an edible fruit or vegetable which has a higher financial value would have to be reduced to a very low level for the project to be highly successful. Likewise, the degree of infestation of a coccid allowed on citrus destined for export is considerably lower than for citrus destined for domestic consumption.

It is especially important for countries embarking on a program of biological control to choose very carefully the pest to be the subject of a research project. The potential for success must be high. The failure of a new project will usually make it more difficult to obtain financial support for subsequent proposals. It is better to demonstrate the feasibility of biological control with a minor pest than to try something too grandiose and fail to achieve the desired results. Therefore, a preliminary evaluation of the potential of a project is very important. This is especially important if it is a first project for a country. Failure can doom more than a project--it can condemn an entire program.

3. Foreign exploration. Once the preliminary information has been compiled and evaluated and it has been decided to continue with the project, then the actual field work can begin. However, before getting on the plane or ship, there are other items that must be considered.

First, a qualified explorer must be elected. The person must have some degree of expertise or training in the field of biological control or ecology. Furthermore, it must be decided if the explorer will go for an extended period of time or will try to accomplish his research in one or more short trips. If there is only one target organism, a single short trip may be sufficient, providing, of course, everything proceeds as planned. Also, it must be established precisely where he will go and at what time of the year.

Assuming this has been done, the next items are the necessary diplomatic and official arrangements. Usually, scientific institutes and scientists are contacted to help arrange for local transportation and space and facilities for work. Often, it is necessary to hire local assistance within the country to be explored.

When the necessary contacts have been made and the administrative matters settled, then the explorer must select the equipment and supplies needed. Van den Bosch (1969) listed the needs of the average explorer for short-term survey and collection trips. The supplies and equipment to be used will be determined by the target organism to be studied and the region to be explored. More equipment would be required to obtain natural enemies of a weed pest found in tropical Brazil than would be necessary to recover parasites of a scale insect in southern France.

Because of the complexity of the actual exploration and survey work, I will not try to cover this subject in any more detail. However, it does require an adaptable and persistent person who is willing to work under all conditions. With a reasonable degree of expertise in the field of biological control and a good knowledge of the target organism, the explorer stands a good chance of success.

4. Manipulation of recovered natural enemies. When the explorer has found natural enemies attacking the target pest, the procedures to be followed depend, in a great part, on the importation and quarantine regulations and quarantine facilities of his own country.

Parasites may be held for emergence by the explorer at the field location. In this case, the desired species are separated from the unwanted ones at the field station. Only the beneficial species are shipped to the receiving station. Another technique is to collect and ship parasitized host material to the quarantine facilities of his country where the material is held for parasite emergence.

Predators are usually shipped directly to the receiving quarantine facilities where they are held, and examined, and any undesired material is eliminated.

Fortunately, certain groups of families or genera are always primary parasites and as such represent a minimum of danger. Here again correct taxonomic determinations are essential. These species usually can be released directly into the field with little or no laboratory studies except for whatever is required to eliminate any possible hyperparasites. However, the phytophagous insects present a more difficult problem. Before they can be safely released in the field, they require more detailed and long-term research including extensive screening and host-range studies. Obviously, this cannot be done during a short field trip. Therefore, it must be done either in the country where the phytophage was found or under the strictest quarantine procedures within the importing country. This latter choice may represent a calculated risk and is avoided if at all possible. This risk must be balanced against the necessity of controlling the pest. A solution may be to establish a temporary field station in the country of origin of the phytophages for most of the preliminary screening tests. Because of the high cost involved in the latter approach, this must be taken into consideration in the preliminary evaluation of the project.

Because of these quarantine problems, I would suggest that priority be placed on projects that can be solved with a minimum of overseas testing. This would still require personnel, training, orientation, and the establishment of adequate facilities. Nevertheless, it would permit a country to proceed with actual work in biological control with a minimum delay.

5. Shipment of beneficial organisms. Although every part of a project is essential, the shipment of the beneficial organisms is a critical phase of the operation. The beneficial organisms must be received alive and healthy at the receiving station or the entire project is a failure. The pests seem

to be hardy and capable of surviving under the most difficult conditions, but their natural enemies are often very tiny and fragile and require very specific conditions for survival. Utilizing the techniques described by Boldt and Drea (1980), most groups of arthropods may be shipped over long distances with a minimum of loss.

It has been my experience that air freight is the most effective form of shipment. Although many natural enemies have stages in their development that will permit long periods enroute, often it is the external conditions of heat and cold during a voyage that are detrimental to the organism. Therefore, a rule to follow is to subject the beneficials to as short a time enroute as possible. In Africa, heat would be a major consideration. Therefore, it would be necessary to ensure rapid action at the entry and clearance points such as shipping, receiving, customs, and quarantine offices. Delays due to bureaucracy in these areas must be reduced to a minimal level.

6. Quarantine facilities and procedures. If a country decides to undertake research in biological control on a permanent basis, then the authorities must seriously consider the establishment of adequate quarantine facilities and the development of a staff to operate these facilities. If the biological control program is to be restricted to obtaining specific, known beneficial organisms from competent sources, then quarantine is of minor importance. Otherwise, the country must be willing to undertake the task of ensuring a responsible quarantine program. It has this obligation not only to protect its own people but to protect the agriculture of its neighboring countries. A mistake made in one country could result in serious consequences for its neighbors.

The actual establishment of quarantine facilities is a major subject in itself and is too vast to be duscussed here. However, I would like to emphasize that if facilities are considered, they must be of high quality--otherwise, they are dangerous. Inadequate quarantine facilities create a false sense of security and as such are probably more dangerous than no facilities at all. An adequate staff is also an important consideration. The benefit of having a building with control chambers, insect-proof greenhouses, and well-equiped laboratories is derived from having a knowledgeable and conscientious staff to utilize these facilities. The quarantine officer and staff occupy very important positions in the research chain of biological control. Their responsibilities are great and, therefore, they must be carefully chosen and must have a deep-rooted concept of quarantine and its potential benefits and dangers.

It is at this stage in the steps of a biological control program when the dependence upon sources of taxonomic expertise becomes the greatest. Before an organism can be released from quarantine for subsequent study and release, the identity of the organism or its relationship to a group of known organisms must be established. This requires an almost complete dependence upon a competent identification organization. Furthermore, the service rendered by these taxonomists must be rapid and dependable.

At this point, the potentially beneficial organism has become available for release from quarantine. By now all undesired species have been eliminated and preserved for reference collection purposes. Furthermore, all accompanying material such as soil, plant material, shipping containers, and other substances of a foreign origin has been destroyed, usually at the time it was received.

7. Study and culture. Unless it is a known species that has originated from a known source, the beneficial organism usually is subjected to additional laboratory studies to determine if it has those characteristics that make it a desired beneficial species. These studies, combined with data obtained from the literature, specialists, and field observations and tests in the country of origin, are the basis on which the organism is either rejected or released from quarantine for use in the biological control project.

Quite often, the beneficial species must be cultured in the laboratory to build up a stock for study and release in the field or to obtain adequate numbers for distribution to other research laboratories.

8. Distribution. Again, the question of shipment is an important issue. By now, the exotic beneficial organism has been cleared and is in the country. However, it must be distributed to scientists in the field or at other laboratories for additional research and release. If a rapid and efficient postal service is available, then this may be used, especially if the distance is not too great. However, considering the size of many of the countries in Africa, I would strongly recommend the use of air freight. In this case, the packaged organisms should be carried to the airport by laboratory personnel and recovered at the destination by laboratory personnel. This is necessary to avoid or settle problems that often arise at the airports. Because the beneficial organisms are usually very tiny and fragile, time is a critical factor. This is especially important if the organisms shipped are the same individuals that were obtained at the foreign source.

9. Field release. This step is the goal of all the efforts to date. Therefore, the releases must be made under the best possible conditions.

Because this is such a critical stage, it must be carefully planned and studied. There should be an abundance of hosts in a susceptible stage, good weather conditions, and access to a variety of permanent habitats. Often, agreements must be made with growers and officials, both governmental and private, to set aside areas for release sites. These sites must be undisturbed by burning, pesticide application, plowing, and other practices that would imperil the establishment of the beneficial organism. The release sites must be well chosen as they represent the climax of a long research procedure and a considerable financial investment.

If the beneficial species becomes established, these sites can be utilized as "field insectaries" for additional natural enemy material for collection and redistribution.

10. Recovery and evaluation. After a beneficial organism has been released, the research is not completed. It must be determined if the beneficial has become established and, if so, where it is established and under what conditions. This information is necessary to determine if the foreign phase of the project is to be continued, repeated, transferred to another foreign locality, or terminated.

The evaluation of an introduced natural enemy is an important stage in any biological control program. Every project must include provisions for an evaluation of the effect of the natural enemy. In the past, too many projects ended with the release of the beneficial organism. There was insufficient effort made to determine if the project was a success as a result of the introduction. Often, populations of the pest species decreased after the natural enemies were released, but there was no definite data obtained to demonstrate that the decline in population was due to the action of the introduced organism. We must have this data to justify the funding of the program. Furthermore, this information is necessary when proposing future programs to consumer groups for support and to administrators who control the funds. Often, the action of a beneficial is not dramatic and can only be demonstrated by careful study. For example, the introduction of natural enemies of the alfalfa weevil in the eastern United States has significantly reduced the number of times that pesticides are now being applied to alfalfa throughout a season. That this reduction was due to the effect of the natural enemies was only demonstrated by a careful evaluation of the impact of the beneficial parasites. Furthermore, the evaluation has shown that the introduction of the natural enemies at a cost of about $825,000 has resulted in a direct savings of about $8 million (Day 1981).

Only in recent years have the projects in biological control been subjected to the type of evaluation that should have been done in the past. As a result, we are convinced that many projects were successful, but we lack the data to prove it. It would be a serious error to make this same mistake in Africa where the need for a sound program of biological control is becoming more and more important. Necessary procedures must be taken early in the planning phase that will avoid repeating the errors of so many past biological control projects.

I have not considered, as such, the procedures pertaining to insect and plant pathogens. I trust this omission is not construed to indicate that I consider these organisms of lesser importance in the field of biological control. The omission is more related to my lack of expertise in this field. Furthermore, research with pathogens (including nematodes) represents a rather different approach and would require a separate series of steps that in themselves would merit at least a second presentation.

There are, however, a few comments I would like to make concerning pathogens and their potential or actual use in Africa.

I would not emphasize research with plant pathogens for the immediate future unless there is a strong research program already in progress within Africa. On this point, I will defer to my colleagues who are much more knowledgeable than I concerning research programs on this continent. I believe this is a very specialized field of research which at present is a high-risk and a high-investment field of study, primarily because of the limited expertise available and the limited amount of experience. Therefore, I believe that research along these lines in Africa should wait until the field is more developed and the countries have established their own pool of experts. The successful use of a plant pathogen to control a weed pest has been admirably demonstrated by the Australian scientists by their work with the rust, Puccinia, released against the weed pest, Chondrilla, in Australia (Marsden et al. 1980). This same rust has been released in the United States with very promising results. Within the United States, we have only two laboratories (at Frederick, Maryland, and Gainesville, Florida) that have been authorized to do research with exotic plant pathogens.

Insect pathogens present a different situation. The risk is less, but the investment in facilities is still quite high. There are several pathogens now available on the commercial market. I would suggest that research be restricted to the utilization of these commercial products until your resources have been developed to the degree that you are ready to enter into this more costly field of research in biological control.

Although a successful project will prove to be safe, permanent, and relatively inexpensive, biological control is not free. To have an effective and viable biological control program, the country or organization involved must be prepared to make a reasonable, initial investment. Research and quarantine facilities must be established and personnel must be trained. The projects in general are long-term and may last for 10 to 15 years. For example, the successful alfalfa weevil project in the U.S. is in its 18th year. The project will continue for several more years in order to distribute to new areas those exotic natural enemies already established in the eastern part of the country. DeBach (1964) stated "over a period of time, the number of successes attained will be proportioned to the amount of research and importation work carried out." In brief, this means that the results obtained will be directly proportional to the funds invested. The alfalfa weevil project cost an estimated $825,000 for the exploration and research, but the results of more than $8,000,000 saved in pesticide application per year more than justify the initial outlay of funds.

Biological control is not the complete answer to all pest problems. It will not completely replace chemical control, cultural control, or other good farming practices. It must be integrated into an overall pest control program. However, biological control is a viable means of pest control. There are numerous examples of successful projects from all parts of the globe. In a recent world review of biological control projects, Clausen (1978) cites several examples from Africa. These included the control of coccids on citrus in South Africa, on coconut in Mauritius, on palms in Algeria and Morocco, and other pests on other crops.

Although the number of successful examples from Africa is relatively small, it can be increased through mutual cooperation, interest, and support. One possible form of cooperation could be the establishment of a West African

Quarantine and Research facility in one of the countries participating at this Conference. This would help distribute the burden among all and permit scientists of all the participating countries to work together to control pests that have no concept of political boundaries. Fortunately, the natural enemies also do not have any consideration of frontiers.

I realize that I have not considered many other fields of research within biological control such as mass rearing and inundative releases, genetic manipulation, the conservation of native natural enemies, as well as the use of pheromones and kairomones. They represent important and potential methods of controlling pest species and should be included in any planning of an overall program of pest control.

In closing, I wish to thank you for the opportunity and the honor you have accorded me by permitting me to appear before this distinguished group. It has been a pleasure to be able to discuss a field of research in which I have been involved throughout my career. I firmly believe that biological control has the solution to many of our pest problems. I hope that in some way I have contributed to a program that will benefit the people of Africa.

References

Boldt, P. E. and J. J. Drea 1980. Packaging and shipping beneficial insects for biological control. FAO Plant Prot. Bull. 28(2):64-71.

Clausen, C. P. 1978. Introduced parasites and predators of arthropod pests and weeds: a world review. U.S. Dept. Agr., Agr. Handbook No. 480, 551 pp.

Day, W. H. 1981. Biological control of the alfalfa weevil in the northeastern United States. In G. C. Papavizas (edit.) Beltsville Symp. Agr. Res. V. Biological control in crop production. Allenheld, Osmon & Co., Montclair, N.J. (in press).

Marsden, J. S., G. E. Martin, D. J. Parham, T. J. Ridsill Smith, and B. G. Johnston 1980. Returns on Australian Agricultural Research. Joint Indust. Assist. Comm.-CSIRO Cost Benefit Study, CSIRO, Canberra, 107 pp.

van den Bosch, R. 1964. In DeBach (edit.) Biological control of insect pests and weeds. Reinhold Publ. Co., New York, 844 pp.

"What are you going to do next week?"

Closing address by John A. Franklin
Regional Training Officer, USAID

Ladies and Gentlemen, This portion of our 4th Annual Conference must end. Before I close the meeting let me take a few minutes to review how and why the USAID Regional Food Crop Protection Project decided to underwrite the major costs of this week's program.

Since the project's birth in 1976, our major objective has been to assist participating countries to improve their capability to increase food crop production through the reduction of losses due to plant pests. An important aspect of effective pest control is to know what control options are available.

The option presented this week has been Biological Control. This option among others such as pesticides, host plant resistance, and improved cultural practices should have a place in each country's effort to reduce crop loss due to pests.

Since BioControl offers possibilities for countries with limited Financial Resources we thought a special effort should be made to explore its potential against pests in West Africa. With that idea in mind, I met with Dr. DRAE (former head of USD/European Parasite Laboratory in Paris in May 1979 and discussed the possibility of a Conference. He agreed to cooperate in our effort , and followed-up on this by participating in the first Annual National Plant Protection Conference in Cameroon, in January 1980. Dr. DREA, Carl CASTLETON, and myself outlined a tentative program, to include specialists from several parts of the world. It was at this time that Carl CASTLETON assumed responsibility for coordinating the steps required to achieve such a Conference.

We were encouraged to continue our efforts by country project officers, several Directors of Crop Protection Services, and some of the distinguished speakers who added so much to this week's program.

When John Gruwell secured funding, the Conference was announced at the 3rd Annual Regional Plant Protection Conference that we held in Nairobi. At that time, we selected Dakar as the Conference site because of its central location and accessibility by air.

A year has passed since Mr. Castleton began his work on the Conference, while carrying out his other training duties as well. We need to recognize that the Conference would not have happened without the efforts that Carl has made.

I would also thank all of you who played a role in the Conference, both as speakers and participants. We're grateful for the competant work of the interpreters, and the cooperation of UNESCO in making the Conference room available.

Our Annual Conference have been financed by USAID in an effort to achieve three goals:

1. To increase contact between researchers and those responsible for Protection of Crops from pre-and Post Harvest Losses.
2. To assist Crop Protection Directors in their decision making by providing timely Plant Protection Information.
3. To help participants identify Additional resources, such as specialists, or institutions that may be able to resolve specific problems.

We feel this Conference has achieved all of these goals. Our project will assist in three more Annual Conferences. The next, focussing on Pesticide Management will be held a year from now in Yaounde, Cameroon. We're attempting to identify appropriate subjects for 1983 and 1984. You can help us with your suggestions. Please make your ideas known to

Mr. Castleton, myself, or any of the **Project Officers.**

Our specific objectives this week were to:

1. Explore existing pest problems in which Biological Control might offer possible solutions to a participating country.
2. Assist participants identify specialists who can provide practical advise on how to proceed.
3. Provde background information on biological control to those participants whose previous knowledge may have been limited.

What are you going to do next week? The longer you wait before following up on an area of interest, the less likely you are to do it at all. This holds true even for those subjects this week that might have capture your interest.

If you have identified an area that you would like to know more about, or that might be tried in your country, what are you going to do about it? Did you identify a specialist who might be able to help you? Did you introduce yourself and explain your problems? Do you need to follow-up with further meetings to discuss specific about what might be required if you were to pursue an interest in biological control? Have you considered appointing a staff member to work at least part-time in Bio-control, and nominating him for the necessary training?

If you have considered these things, but have hesitated because of limited funds, I would hasten to point out that although funding is a valid concern, it doesn't mean that it is impossible. If you were to start today to express specific interests, many of the organizations which have been represented here this week would be able to help to varying degrees.

In the eight countries, out of the ten present, in which our project is active, feel free to discuss your interests and needs with our officers, to make sure you know who they are, let me point out:

Mr. William Overholt - Mauritania
Mr. William Settle - Senegal
Ms. Celeste Welty - The Gambia
Dr. Jerry Fowler - Guinea-Bissau / Cape Verde
Dr. David Perkins - Cameroon

All these members of the Regional Plant Protection Project are assigned to assist countries identify pest problems and find ways to carry out programs of effective pest management.

The value of this conference is not measured by whether you had a good time, but what you do when you get home.

What are you going to do next week? Follow-up by contacting someone by letter, or similar concrete step, or only just think about it? Biological Control, like all worthwhile actions, doesn't happen by accident. It requires someone to take planned action. That someone is you!

Let me now officially close this week's Conference. It has been a pleasure for us to have been associated with you. I hope we can meet again in the near future. Until then, good-bye, and a safe journey home.

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