

PEST CONTROL BY BIOLOGICAL AGENTS

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Rice and vegetable crops are the main products of agriculture from the small farms. To increase the productivity of these farms it is necessary to identify and control the losses. The overall national loss of the rice harvest is estimated to be about 20%. A further 10% loss occurs after the harvest. The losses in the vegetable crops are considerably higher. These losses are caused by diseases, insect pests, weeds and animals.

Chemical agents for the control of agricultural pests have been used for many years and have been fairly successful. The use of toxic chemicals throughout the country introduces a new hazard and danger to the human population. These chemicals are used as sprays or as systemic pesticides, the latter cannot be washed away as they are in the plant tissues and the danger of cumulative poisoning, over a period of time, is now recognised as a definite health hazard for persons who eat such vegetables. These toxic chemicals are also dangerous to the workers who use them and accidental poisoning is common when precautions are not taken.

Imported chemical pesticides are costly and an ever increasing continuous drain on foreign exchange, therefore any substitute which can save foreign exchange will be welcome. Chemical pesticides used in agriculture have created a new problem for the malaria control program. Mosquitoes which spread malaria have become resistant to chemical pesticides so that control becomes ineffective.

Because of these many disadvantages and dangers, alternative methods for pest control are being examined. The most promising of these appears to be biological control. This method attempts to use the natural enemies of pests to destroy them and thereby to control their numbers. Bacteria, viruses, fungi and insects are identified and their biological characteristics studied so that they can be produced in the laboratory in large numbers. These are released in the pest affected areas wherever necessary.

Research work in biological control in Sri Lanka is done at the Central Agricultural Research Institute, Gannoruwa, which collaborates with the Commonwealth Institute of Biological Control through its Indian laboratories in Bangalore. A consultant from this laboratory will soon visit Sri Lanka to work at the Gannoruwa Research Station. Advice and guidance from research workers in the region will be invaluable.

The first bacterial agent developed for bio-control was the Bacillus thuringiensis - H14, in 1967. Extensive field trials have been carried out for the control of vegetable crop pests.

Bio-control has been attempted to check the tea tortrix - Homona coffearia and the coconut caterpillar - Nephantis seneriopa. The coconut leaf-miner, Promecotheca cumingi, a recent introduction to Sri Lanka, caused widespread damage and was finally checked by biological control.

employing the parasite the Dimmockia javanica.

The bio-control of the pests of rice and other vegetable crops has received little attention and provides a wide field and extensive scope for investigation. The cabbage pest - the Diamond Back Moth - though chemical control is extensively used, causes losses up to 80%. Natural enemies which parasitize the larva and pupa and a virus infection are now being studied as a control agent. Similarly attempts are being made to control the bean fly - a serious pest of legumes, the tomato fruit borer and the melon fly a pest of the bitter gourd and snake gourd. Losses are estimated as high as 50%. Chemical control of the pests is widely used with varying degrees of success. Bio-control has not been attempted though the known parasites

from Sri Lanka have been introduced in Mauritius and Hawaii.

Biological control of the malaria and filaria mosquito is receiving World Health Organisation (WHO) funding. The Bacillus thuringiensis and sphaericus have been identified as successful larvicides and field trials are now being conducted in Thailand. Other predators of mosquito larvae such as fungi, nematodes and fish are under investigation. An alternative to chemicals is urgently necessary since the mosquito appears to develop resistance fairly rapidly. Research in biological control needs to be extended by providing more trained research staff and funds. A biological control laboratory within the Central Agricultural Research Institute when established should be able to do very useful work. Funds may be available through the USA-Sri Lanka Science Agreement.

TECHNOLOGY OF GENETICS

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Many centuries ago man gave up his hunting and nomadic habits and settled down to grow plants and rear animals. He selected the seeds of the plants, and mated the animals, showing characters in them which he liked, to breed the next generation. In this way primitive man began very slowly to improve his crops and livestock in quality and in quantity so as to produce more food and clothing for himself. With the more settled way of life he could now enjoy, he was able also to leisurely think about his diseases and also perhaps to relate some of them to his own heredity.

This trend of affairs continued until long after modern civilization as we know it had begun. Although man could manipulate his plants and animals to obtain improved varieties he still did not know how this was brought about. The basic mechanisms of inheritance were still shrouded in mystery, myth and superstition. It was generally believed, even as late as the last century, that the characters of the mother and the father were mixed in equal proportions in the children, although everyday life would have surely demonstrated that this was not so. Any concepts of inheritance which they had, too were based purely on empirical observations and intuitive reasoning.

Then in 1866, a Roman Catholic monk in Austria, Gregor Mendel, published a paper, in German, in an obscure natural history journal of that country. This was to change the entire outlook of man. Using very simple but elegant and rigorously scientific methods, and mathematically

analysing his results, which was unusual for a biologist at that time, he announced to the world the hitherto, secret laws of inheritance! He was ahead of his times, however, as most trail-blazers are. No one at that time understood what he said; for 34 long years this treasure lay buried in the shiftless sands of ignorance.

After his death, three European botanists, de Vries, Correns and Tschermak, independently carrying out experiments similar to those of Mendel stumbled upon the same truths about inheritance, and they introduced Mendel in 1900 to the scientific world and explained the significance of his work. The Science of Genetics is therefore, actually a product of this century.

According to Mendel, characters are produced in animals and plants by the action in them of unseen factors or particles which are the ones that are transmitted from generation to generation in the reproductive cells. He further showed that to explain his experimental findings, these factors, which we now call genes, must act in pairs to produce each character in the plant or animal but that they separate into the individual factors in the germ cells. In the paired condition, one factor could suppress the effects of the other, or in other words, one factor could be dominant and the other recessive. This concept of the particulate nature of a hereditary material and their dominance and recessivity proved to be the essence of the new science of genetics. He further showed that such pairs of factors for different

characters could combine at random in different ways in each generation.

With this methodological and conceptual breakthrough in the understanding of the processes of inheritance, new vistas of genetical knowledge opened up. Very soon it was shown by other geneticists that genes are linked to one another in groups, like strings of beads, and that beads from one string could exchange places with beads of its complementary string; that genes are actually carried on paired structures called chromosomes inside the nuclei of cells and seen only through a microscope, that the genes are made of a chemical substance called deoxyribonucleic acid, or more popularly as DNA; that DNA has a definite structure which beautifully accounts for all the known properties of a hereditary material; that this DNA stores all the information in code for producing proteins that go to form the organism, and that although DNA is very stable under normal conditions producing exact copies of itself, sometimes spontaneously, or under the effect of certain irradiations and chemicals, the codes get altered producing changes in the genes, these are termed mutations.

With the expanding mass of basic knowledge, genetics soon became a flourishing technology. This technology of inheritance has produced dramatic, important and practical results for the farmer and the animal breeder.

The application of the new technology to plants has produced by far the greatest economic benefits to man.

The cultivated plants which are of paramount importance to man as they serve as the basic source of energy-giving food for him and his livestock are the cereals, rice, wheat and maize. Selective breeding programmes on these plants to improve their yields, their protein content and to make them resistant to pests and diseases form the single largest research endeavour of geneticists in the whole world.

Selective breeding is where individuals showing the desired characters are selected to breed the next generation. This is very similar to what ancient man practised, but

with a difference. It is more sophisticated, more efficient, and produces the desired results in a very short time. They are no longer trial and error methods. Certain characters have a high genetic component and only these characters can be manipulated by selective breeding. Other characters have very little genetic variability but can be influenced by environmental factors. Such characters usually cannot be improved by selective breeding methods but depend on cultural practices, namely the way they are grown, to show improvements. To distinguish between these two types of characters requires a great deal of careful experimentation.

In mutation, breeding seeds are treated with substances which induce changes in genes, and the new mutant genes are then subjected to selection. This is a very wasteful process as very often the changes produced in the seeds are harmful and may even kill them or produce unwanted characters in the plants that grow from such treated seeds. Few useful changes are effected by this method, but where large numbers of seeds or individuals are available for treatment as with cereals or micro-organisms, this technique does give quick and economical results. In the yeasts and other fungi this method has been exploited to increase the yields and improve the quality of their products such as alcohol and antibiotics.

The third method of breeding - hybridization - makes use of the fact that when different strains of plants of the same species, such as maize, are crossed, the resultant seeds give rise to plants which are very vigorous in growth and extremely hardy towards pests and diseases. This phenomenon, called hybrid vigour or heterosis, has produced such bumper harvests, especially of maize in the United States, that the profits from the increased yields are said to have paid for all research activities in genetics up to the present time.

Using similar methods of breeding other plants such as vegetables, pulses, tea, rubber, coconut, cotton, tobacco, ornamental flowers and even forest trees have been improved to give higher yields of their products which are of better quality.

In certain plants like tea, for instance, once good strains have been bred they are propagated vegetatively as clones. Clones are genetically uniform cultures that are easy to cultivate on a large commercial scale.

With the help of the new technology of applied genetics, improvements in the quality and quantity of animals, and the control and elimination of pests and diseases have been achieved.

The greatest amount of research on animals goes into improving the production of food in terms of meat, eggs and milk by means of selective breeding. Breeding of horses, sheep, fish, dogs, cats, pigeons and various other pets to obtain useful and fanciful strains are carried out in the same way. Mutation breeding methods are used in the case of silkworms, bees and other useful insects where large numbers of eggs are easily obtainable and the generation time is short.

In the breeding programmes of large animals special use is made of two techniques. One, is the progeny testing of individual animals. In these tests, the genetic constitution of individual animals which are mainly males, are assessed by mating them to a number of different females and examining their progeny. Once a good male is detected having the genes for desirable characters then it is used as a stud for obtaining large numbers of progeny with those desirable characters for commercial purposes. A further improvement is in the use of the second of the techniques, namely, artificial insemination or AI. The sperms of the selected male is extracted and frozen and stored. Whenever the need arises they are thawed and used to inseminate a large number of females. In fact, the sperms of donor animals can be used in this fashion long after the animals are dead and gone. In advanced countries sperm banks, in fact, are maintained to cater to the needs of animal breeders. This has recently been extended to the sperms of humans as well.

With the use of AI, a further refinement in animal breeding has been introduced. Normally equal numbers of males and females are born to animals. But in certain

instances as in dairy farming it is advantageous to have more female offspring than males. This is achieved with a reasonable degree of success by making use of our knowledge of how sex is determined. In cattle, as in other mammals including human beings, as also in insects, sex is determined at fertilization by a chromosomal mechanism. In the nuclei of all cells there are pairs of identical chromosomes, but in male cells the two members of one pair is not identical in size and appearance. These are called the sex chromosomes and are designated X and Y, of which the X is the larger one. In the female cells there are two X chromosomes. When these chromosomes separate into the germ cells, each ovum or egg cell in the female would have an X chromosome and all the egg cells would be identical. But the sperm in the male are of two types, the X chromosome bearing sperm and the Y chromosome bearing sperm. Because the X chromosome is larger than the Y, the X sperm is heavier than the Y sperm. Centrifuging the seminal fluid separates to a certain extent the two types of sperm. Now when the fraction of fluid containing more of the heavier X sperm and less of the lighter Y sperm is used to inseminate a cow, the chance of getting a female calf is considerably increased. If males are required, as in the meat industry, then the lighter fraction of the fluid could be used to get more males. Electrophoresis as well as pH can also be used to separate quantitatively these X and Y sperms.

In the case of poultry, as in all birds, fish and moths, the mechanism of sex determination is just the opposite, two X chromosomes producing a male and an X and Y a female (actually called Z and W chromosomes). In poultry the sex of chicks is not distinguishable even two weeks after hatching and commercially it is definitely economical to know the sex of the chicks at least as they hatch out. The use of suitable genetic markers to give differently coloured males and females have been tried and proved successful in differentiating sex, but the majority of poultry farmers have not taken to the idea.

With regard to pest control, various genetic methods are used, particularly for controlling insect pests. The most

successful and popular method is the sterile male technique. Irradiations or chemical mutagens are used to induce sterility in the male insect pests. This sterility is caused by the damage of the chromosomes in their sperm due to the treatment, without in any way affecting the viability of the sperm itself. When eggs of normal females are fertilized by these sperm they fail to hatch. In this way repeated releases of sterile males into pest infested regions will completely eliminate them from those areas. The success of this method was dramatically demonstrated in the USA when the screw-worm fly whose grubs eat into the flesh of cattle, was completely eliminated from the infested areas of that country.

Treatment of insects with mutagens can also induce, what are called translocations. These are exchanges of parts of dissimilar chromosomes and they produce semi-sterility in the individuals which have them. That is, half their germ cells are sterile. In this way the population of pests could be reduced. The important advantage in this method is that the translocation is carried into the next generation in increased numbers and help to depress the population size still further. There are many other genetic mechanisms which can be exploited for the control of pests. Out of all the methods of pest control the genetic methods are the safest to use, but they are very sophisticated and involve a great deal of effort and money for their successful exploitation. Still with the serious threat of global pollution with chemical pesticides and the hazards of other biological methods of control, very serious attention should be paid by entomologists to these genetic methods of control.

Finally we shall consider the important part genetical knowledge plays in relieving man from the sufferings caused by disease.

Cancers are due to some cells in the body becoming wayward and dividing too soon and too often, and in this uncontrolled fashion producing malignant growths. Irradiations and chemical mutagens disrupt the chromosomes of these fast dividing cells and as in the sterile male method cause cell death. In this way the growth of

cancers is arrested. The origins and the causes of cancers are not yet fully understood, although it is known that some are due to viruses. Active research in molecular genetics is being pursued in the advanced countries to understand this cancer problem.

There are various diseases of man caused directly by genes. Some may be relatively harmless abnormalities like colour blindness and polydactyly, which is the presence of extra digits in hands and feet. Others are very serious and deadly, like haemophilia, the bleeding disease; phenylketonuria, a biochemical disease where certain substances accumulate in the body with lethal effects on the nervous systems of babies, muscular dystrophy, which results in the withering of muscles of the body; sickle-cell anaemia, a disease affecting the red blood cells and causing death in infancy, and so on. There are two ways in which these diseases could be prevented. The easiest way is to avoid marriage of two persons whose families are known to have had the same disease. Here we run into a practical difficulty. If two persons are in love with each other it would be difficult to prevent their marriage even if they know that they harbour dangerous genes in them. The other method is to recognise the genetic causes early and to prevent the expression of those bad genes. For example, in the case of haemophilia, bleeding can be stemmed by giving the patient a chemical called antihaemophilic factor of AHP for short, which is the substance they are deficient in. In the case of phenylketonuria which is the inability to break down further the amino acid, phenylalanine, if this condition is recognised in early infancy, then the infant can be maintained on special diets which are deficient in that particular amino acid. In this way a horrible, convulsive death can be prevented, and the individual could grow into a normal adult. Not all genetic diseases can be controlled in this fashion.

Certain abnormalities arise in individuals due to chromosomal aberrations. Bisexual individuals or hermaphrodites, mongol idiots, are some of these abnormal beings. Generally such abnormalities arise when slightly older women give birth to

children, and the only way to prevent such births is for older women not to conceive.

If we now turn to another aspect of the genetics of man we see that human populations belong to different blood groups that are determined by genes. Apart from the complications which arise in giving blood transfusions where these types have to be matched before use, the blood group systems cause secondary complications. The rhesus system particularly is the most dangerous of these groups. If a rhesus negative woman conceives a rhesus positive baby then the blood cells of the foetus could migrate through the placenta into the blood system of the mother and the antigens in these foreign blood would induce the mother to secrete antibodies. These antibodies could get back into the foetus or a subsequent foetus and attack and destroy its red blood cells. This causes the condition known as erythroblastosis foetalis giving rise to a still-birth. If this condition is recognised in the first month of pregnancy then, only a blood transfusion of the foetus through the mother's body can save it. The action of the rhesus group on pregnancies is not quite so straightforward in that their action is minimised by the other blood group system, the ABO group. Apart from these complications, the blood groups genes have effects on other organs of the body. For instance in the ABO system persons belonging to certain groups are also known to be predisposed to certain types of diseases like cancers and peptic ulcers. The blood group genes can be put to good use. They can be used to exonerate a man from the accusation of being the father of illegitimate children in a paternity suit. If the child's blood group does not tally with that of the man then he definitely could not be the child's father.

In Sri Lanka much work has been done with this new technology. Improved varieties of rice, tea, rubber and coconut and of many other crops have been produced. Improvements in quality and in quantity have been achieved in cattle and poultry breeding for improvements in the production of milk and eggs. A great deal of unnecessary human suffering and pain has been reduced by application of genetics in medicine. I hope that such application would increase considerably in the future so that we could make Sri Lanka completely self sufficient in our basic requirements of food. We may not be able to rid ourselves of hereditary diseases, but we could at least relieve human suffering to a large extent through the knowledge of genetics in genetic counselling.

As for the future technology of genetics, our present knowledge of basic genetics may make it possible to manipulate genes in such a way as to alter individual genes of animals, plants and ourselves, to our liking. Lasers could perhaps be used to cauterize harmful genes without disturbing adjacent ones in their molecular environment; genes made to order in test tubes could, perhaps, be inserted into the genomes of individual organisms, or we could have chemicals on our benches which would alter specific genes the way we want to change them. This type of genetic engineering and directed mutagenesis, like many of the great discoveries in science, is rapidly passing from the realm of science fiction and fantasy to become a wonderful new technique for the benefit of man.

BIOLOGICAL CONTROL OF COCONUT PESTS

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Coconut, *Cocos nucifera* L., occupies about 412,000 ha (1 million ac) of land in Sri Lanka, and is a major plantation industry. Its contribution to the national economy is well documented and has been about 5% of the total GDP in 1982. Sri Lankans consume as much as 116 coconuts per annum, which provide about 22% of the daily caloric intake. It is also the main source of dietary fat and appears to be the sole source of fat for the lower income groups.

The coconut palm is attacked by a number of insect pests. The coconut caterpillar, *Opisina arenosella*, (Lep. Cryptophasidae), (earlier referred to as *Nephantis serinopa*), the Red Weevil, *Rhynchoporus ferrugineus* (Col. Curculinidae), the Coconut Scale, *Aspidiotus destructor*, (Hom. Diaspididae) and the Black Beetle, *Oryctes rhinoceros* (Col. Scarabaeidae) are the important pests at the moment. The coconut leaf miner, *Promecotheca cuningi* (Col. Hispidae) caused extensive damage to coconut plantations about a decade ago but is under very satisfactory control. The Nettle Grub, *Parasa lepida* (Lep. Limacodidae), the Bag worm, *Manatha albipes* (Lep. Psychidae) the Yellow Spotted locust, *Aularchis miliaris* (Ortho. Acrididae) and the termites *Odontotermis* spp. are minor pests of coconut.

Generally, pest control is taken to mean insecticide spraying. The stature and geometry of adult coconut palms preclude such traditional crop protection measures as spraying of insecticides. It was therefore necessary for the scientists to develop alternative methods of pest control in coconut. At the Coconut Research Institute (CRI) of Sri Lanka, a programme of biological control using naturally - occurring parasitic and predatory insects was launched in the 1950's. This is perhaps

the first documented, organised attempt of biological control in Sri Lanka.

Biological control affords a number of advantages. It is a low cost method, ideal for small holders, which constitute about 70% of the coconut holdings. The permanency of the control achieved, and the lack of harmful undesirable effects on the environment with no danger to man and other non-target organisms are factors which merit serious consideration.

Since inception, the biological control programmes at the CRI has developed a gamut of activities. Some of the important developments are documented below:

1. The Coconut Caterpillar, *Opisina arenosella*

The Coconut Caterpillar is a serious pest of coconut, particularly prevalent in the Southern, Eastern and the Western Provinces. Outbreaks are often noticed during periods of dry weather. The damage is caused by the caterpillar stage, which feeds on the green tissue of the leaf resulting in dried brownish patches. At the same time, the caterpillars make galleries out of frass. When a large number of caterpillars are present, heavy feeding would result in a large proportion of the leaf turning brown. The caterpillar pupates in the leaf, and the adult moth facilitates spread of the pest.

In 1940's and early 50's, the pest was controlled by spraying insecticides. This was an expensive and a laborious process. The biological control programme was launched with the breeding and release of the pupal parasite, *Trichospilus pupivora*. Since then, research has identified several different parasitic hymenopterous insects which attack different development stages of this pest.

These are as follows:

Larval parasites - Perisierola nephandidis
(Bethyilidae)
Eriborus trochanteratus
(Ichneumonidae)
Bracon hebator
(Braconidae)

Pupal parasites - Trichospilus pupivora
(Eulophidae)
Antrocephalus pandens
(Chalcidae)

Egg parasite - Trichogramma braziliensis
(Trichogrammatidae)

The Coconut Research Institute established two insectories, one at Lunuwila and the other at Mylambavelly in the Eastern Province to multiply these parasites. The parasites are bred on alternate hosts such as Prodenia litura (Lep. Noctuidae) or Corcyra cephalonica (Lep. Galleridae), which can be raised without much effort. The parasites are packed in glass tubes well before their emergence from the cocoons, and despatched by post to affected estates in wooden boxes. The despatch is so timed that when the tubes reach the estate, the adult parasites would have just emerged and ready for release in the field.

In the case of the coconut caterpillar, it has become necessary to regularly release the parasites to augment the field population. The results achieved have not been entirely successful. At present, techniques are being developed to use biological control as a part of the integrated control that is being attempted on the coconut caterpillar.

2. The Coconut Leaf Miner, Promecotheca cuningi

This pest was inadvertently introduced to Sri Lanka in 1970, and was detected at Dehiwala. The adult female lays eggs on the underside of coconut leaflets and the resulting larvae feed on the leaf tissue while lodged between the upper and the lower epidermis in a mine. An estimated 30,000 ac was rapidly invaded by the pest. The attack was so devastating that the total destruction of the coconut industry seemed a distinct and imminent possibility.

The control of this pest is now recorded as a remarkable event in the annals of pest management in Sri Lanka. A nucleus culture of about 10 hymenopterous parasites was imported to the country from Fiji. This consisted of the larval parasite, Dimmockia javanica (Eulophidae) and the larval and pupal parasite, Pediobius parvulus (Eulophidae). These were bred in the laboratory on the pest larva and released in the field. Dimmockia javanica was the most successful parasite.

The modus operandi of this parasitic insect is spectacular. Once released in affected areas, they would walk on the leaf surface and seek, by instant, the larvae of Promecotheca which live in a mine in between the two surfaces, in the leaflet. Once located, the parasite would deposit its eggs on the body of Promecotheca larva by piercing the epidermis using the fine sword-like ovipositor (Fig.1). Parasite larvae would emerge from the eggs and would devour Promecotheca larva thereby controlling the pest. At the same time, the parasite multiplies.

In a couple of years the pest had all but disappeared as dramatically as it came and the coconut industry was saved from total destruction at a very low cost, which was estimated at about 1% of the annual export earnings from coconut products.

3. The Coconut Scale, Aspidiotus destructor

The Coconut Scale is a sucking insect found on the underside of the leaflets. In outbreaks, large areas become yellow due to the damage done to the leaflets by the scale insects. The CRI developed a biological control programme for this pest by harnessing the activity of naturally-occurring predatory insects. During the mid 1980's, large numbers of the predatory lady bird beetles Chilocorus nigritis, and Pullus xerampelinus were multiplied in the laboratory and released in the field. The different development stages of the lady bird beetle devour the scale insects, thereby controlling it. At present, the scale pest is kept in a very satisfactory state of control. Whenever a slight outbreak of the pest is encountered, the predatory lady bird beetles also follow, thereby keeping the pest under control.

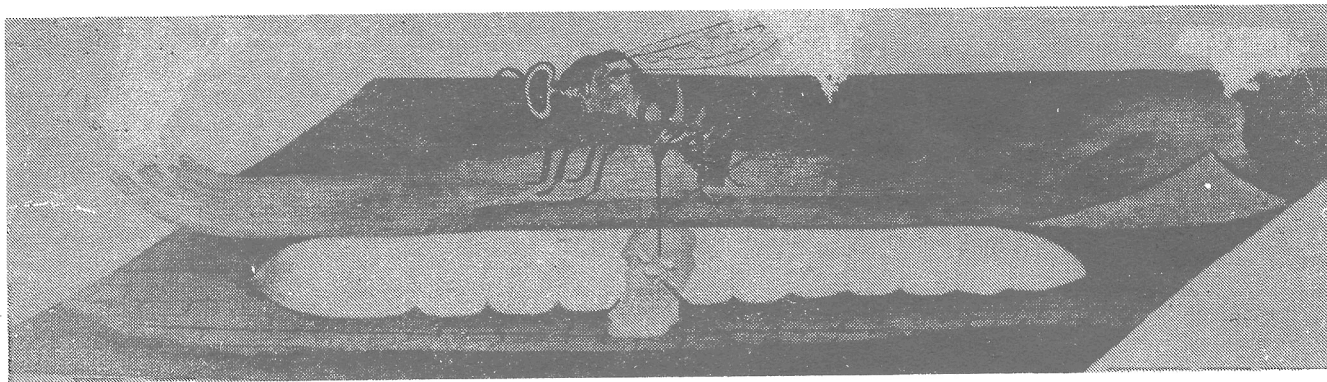


Fig. 1 - Parasitization of Promecotheca larva

The parasite uses its ovipositor to pierce the leaf surface and deposit eggs in the body of the pest larva

4. The Black Beetle, Oryctes rhinoceros

The Black beetle is a common pest of coconut. The adult is a large beetle, about 40 mm in length. It is shiny black on the upper side and could easily be identified by the characteristic backwardly curved horn on the head. Damage is caused by the adult when it feeds on the unopened tender fronds. When these damaged fronds eventually grow out, the leaves appear neatly cut with a scissor.

The pest breeds in coconut logs and in other decaying vegetable matter. The grayish white larvae, which when fully grown up would be about 40-45 mm, could be seen in breeding places.

A biological control programme was developed recently to control this pest. This involves the use of a fungus, Metarhizium anisopliae and a virus Baculovirus oryctes. The use of a nematode is also being investigated.

The fungus would attack the larvae and cause death. At the same time, it multiplies and the fungal spores are spread by wind and adult beetles. The virus causes a pathological condition in the gut of the larvae thereby killing it. In the field, the virus is transmitted quickly, mainly by the adult beetles.

5. Control of Chromolaena odorata (earlier called Eupatorium odoratum)

Chromolaena odorata is a pernicious weed in coconut lands. When allowed to grow rank, cultural operations and coconut collection

become very difficult.

The CRI introduced an insect in mid 1970's in an attempt to control this weed. The caterpillar stage of the lepidopterous insect, Parauchaetes pseudoinculata (Arctiidae) is a defoliator and has been observed to be a voracious feeder of the weed. When the caterpillars are present in large numbers the weeds are readily defoliated. Although defoliation in itself cannot kill the weed, repeated action by the insect weakens the plant, often reducing it to wood only. If the climatic conditions are adverse to the weed, it often dies after defoliation. Complete success has not been achieved yet.

Circumstances have compelled the use of biological control in coconut pest management. This has proved to be of commendable foresight, as has been evidenced from the results obtained so far. The advantages and the value of these methods have been amply demonstrated. Biological control is relatively cheap and easy to apply compared to the other control methods such as insecticide application. Sometimes, however, biological control is a relatively slow process to produce quick results, but nevertheless, the results are longer lasting. It has also to be done under supervision. The advantages of biological control outweighs the disadvantages, particularly in a crop like coconut. It is because of this that continuous research is being carried out to improve biological control techniques and to find more biological control agents.

BIOLOGICAL CONTROL OF THE DISEASES OF THE HEVEA RUBBER TREE

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INTRODUCTION

It is important to define what is meant by "biological control of plant diseases", before setting out to describe the efficacy of such systems developed for any crop plant. Most plant diseases are caused by fungi; and the usual method of controlling such diseases is to use a fungicide, which will effectively kill off the fungus, eliminating the disease. However, there are other methods of controlling plant diseases or reducing their economic effect, so that the damage caused is minimal and monetary losses are contained. The use of resistant plants, adjusting planting date or depth of planting, so as to reduce disease incidence (disease escape), applying the knowledge available on the factors leading to disease severity to avoid plant disease epidemics, reducing the inoculum potential of the pathogen by various devices to reduce infection, altering the soil organic matter content or reaction, so as to create conditions inimical to the pathogen and all other devices that can be used to reduce or eliminate the use of fungicides, can be regarded as biological means of controlling diseases. We will use this broad concept of the subject, in this paper, in order to describe the many facets of this interesting problem, as it applies to the rubber industry, pointing out the success we have achieved, by intensive study of simple ideas and fitting the data on to a larger canvas, to find solutions to the original question.

The rubber tree (Hevea brasiliensis, Muell.Arg.) is susceptible to a number of diseases, like most other crop plants. The diseases of economic importance of this tree in Sri Lanka are the following, grouped according to the parts of the plant affected by each disease:

Root - white root and black root disease, caused by Rigidoporus lignosus and Xylaria thwaitesii, respectively.

Stem and bark - bark rot and die back, caused by Phytophthora meadii

Leaf - Oidium leaf disease, caused by Oidium heveae, Phytophthora leaf fall caused by Phytophthora meadii and Gloeosporium leaf disease caused by Colletotrichum gloeosporioides

Intensive studies have been carried out on all these diseases by the Rubber Research Institute of Sri Lanka (RRISL) and, in nearly all cases, successful methods for their biological control have been developed, based on data gathered on the biology of the causal fungus of each disease, its methods of infection and spread in the field, and the effect of weather conditions on the severity of the disease. These methods have been tried and tested over several years, generally from about the early 1960s, so that we now spend very little money on the control of the diseases of the rubber tree. This is one of the important factors that has contributed to the survival of the rubber industry in Sri Lanka; as costs of disease control have been reduced from about =/12 cts per kg of dry rubber produced, to about half a cent per kg.

ROOT DISEASES

There are several root diseases affecting rubber trees in different countries, but the only one of economic importance in Sri Lanka is white root disease, caused by the fungus R. lignosus. This is considered to be the most important disease of rubber today (Liyanaage, 1977a). Black root

disease, caused by *X. thwaitii* occurs only in certain parts of Sri Lanka, mainly in the Kegalle District. This is as virulent a disease as the former; but due to its restricted distribution it is not as important. Essentially the same methods are recommended for the control of both diseases, so that only white root disease will be described in detail here. Both diseases are essentially replant diseases i.e. their incidence creates a problem mainly in replanted areas.

Elimination of inoculum

The fungi *R. lignosus*, is a weak parasite, in the sense that it requires a large source of inoculum, usually an infected old root, to cause infection of a new plant. Therefore, one of the classical methods of controlling this disease was to prepare a disease free area for planting rubber, by uprooting and burning all roots infected by root diseases at the time of planting. All vegetable matter rots after a certain period of burial in the soil. Therefore, the same result as uprooting and burning can be achieved by leaving the soil fallow for 1-2 years before replanting, so as to enable infected roots time to rot. The same result can be achieved by another neat method by changing the planting position at each round of replanting. This gives time for infected roots of the previous trees to disintegrate before the roots of the new replants reach them (Liyanage et al, 1984).

Intensification of rotting

We have also found that any method of encouraging the rate of rotting of old infected roots, in replanted areas, reduces the incidence (Liyanage & Peries, 1984) of white root disease (Liyanage & Peries, 1983). Two methods are usually recommended; (a) the use of various chemicals on the cut surfaces of tree stumps eg urea, borates and certain hormones, (b) the growth of legume ground covers in replanted areas, which apparently encourage the growth of wood rotting fungi and bacteria (Liyanage, 1980). This method also depends on the principle that a large source of inoculum is necessary to cause infection and contact must be established between the healthy root and the fungus, for infection to take place. Therefore, the more rapid the rate of wood rot, the less chance there is for contact between healthy roots and the

pathogen before the source of inoculum becomes too small to support an infection.

Soil amendment

The composition of the soil microbial content can be altered by various methods such as altering the soil reaction, its nutritive content or its organic matter composition. The RRISL recommends the use of approximately 110 g of sulphur per square metre of soil surface in infected sites, to reduce the incidence of this disease (Peries et al, 1964). The addition of sulphur rapidly increases the acidity of the soil and increases the population of *Trichoderma* spp. and *Penicillium* spp. in the soil. Both these fungal species are antagonistic to the pathogen and reduces disease incidence in high risk areas. Sulphur is very expensive now, and its use is recommended only in areas where the old rubber stand showed a high incidence of white root disease (Peries & Liyanage, 1983).

STEM AND BARK DISEASES

The only stem and bark diseases of any significance on *Hevea* in Sri Lanka are stem die back of young plants and bark rot of mature trees, both caused by *P. meadii*. Both these diseases have been successfully controlled in our country by biological means. The main source of infection by *P. meadii* is the zoospore, which is produced almost entirely on mature rubber pods. Our strategy to reduce disease incidence is to reduce pod set in rubber trees to a bare minimum, just sufficient to produce enough seed for the rubber stock nurseries. This happy situation is achieved by the judicious control of *Oidium* leaf disease. The causal fungus of this disease, *O. heveae*, also infects rubber flowers. Therefore, by reducing the intensity of *Oidium* control, and letting the fungus, infect a majority of rubber flowers, we have reduced pod set and thereby reduced the substrate on which *P. meadii* can grow and sporulate (Liyanage & Peries, 1983 b). This strategy has enabled us not only to reduce expenditure on *Oidium* leaf disease control, but virtually eliminate the necessity to control *Phytophthora* die back and bark rot.

In the rare cases where shoot die back of young plants does occur now, we have found that it is more important to pick off the rubber pods from the mature trees surrounding the young replanted area rather than use fungicides to control the disease on affected plants. The incidence of this disease is rare at present; because estate managers are alive to the fact that young plants should not be placed in the shadow of mature trees, bearing large numbers of infected pods, and take necessary action to avoid this.

The use of fungicides, for the control of bark rot, has practically been eliminated since the mid - 1960s in Sri Lanka; because, in addition to the reduction in pod set, the RRISL has insisted that rubber trees should not be tapped soon after rain, when there are pods infected by P. meadii on the trees (Peries, 1975). This is because there is always the possibility that the zoospores of the fungus will swim down to the tapping cut, in the surface moisture, and cause bark rot infection, if tapping is done before the moisture dries off the surface of the tree. This advice and its acceptance by rubber growers has made bark rot of rubber trees an unusual sight in Sri Lanka - a far cry from the situation in the 1950s, when all estates used bark rot fungicides as a routine measure on all mature clearings.

LEAF DISEASES

There were three leaf diseases of Hevea of economic importance in Sri Lanka up to mid - 1960s; however, now except for Gloeosporium leaf disease, which causes some concern in wet years on young replanted rubber, these diseases cause no economic damage in this country any longer. This satisfactory position has been achieved by the development of biological methods of control that keep their incidence at sub-economic levels.

Oidium leaf disease

The most important methods of controlling Oidium leaf disease in Sri Lanka are: (a) the use of disease tolerant clones and (b) the restriction of rubber planting to areas below 300 m above mean sea level. This together with the fact that we have

found that, the incidence of Phytophthora leaf, bark and stem diseases can be kept down to satisfactory levels by allowing a large proportion of flowers to be infected by this pathogen and thus abort themselves, has helped us eliminate the expenses on Oidium control.

The clones like Tjir 1 and BD 5, which were popular in Sri Lanka up to the early 1950s had thin cuticles and the new leaf surfaces took a long time to harden after bud-burst. This allowed the conidia of the pathogen ample time to germinate on the leaf surfaces, penetrate into the leaf and establish infection. The most popular clone, used in the early days of the rubber replanting subsidy scheme (RRSS), started in 1953, was PB 86. The leaves of this clone have a thicker cuticle and one of its most important characteristics is the rapidity with which leaf fall is followed by refoliation and the hardening of the cuticle after wintering. The new leaves of PB 86 reach maturity in about 7 days compared to about 10-14 days in clones like Tjir 1 and BD 5. Therefore, sulphur dusting is not required to control Oidium on clone PB 86, at sea level and elevations up to 2-300m above mean sea level.

The pathogen causing Oidium leaf disease grows best under conditions of high humidity, temperatures slightly lower than normal for the wet low country areas i.e. at 25-28°C, low light intensities and the absence of prolonged rainfall. Therefore, the disease caused by O. heveae is more virulent in areas where there is heavy mist in the mornings, occasional showers in the evenings with clear nights and slightly lower temperatures: conditions more likely to occur at higher elevations, above 300 m, than at sea level or the low country elevations. These are the reasons why the RRISL recommends that rubber be planted at elevations below 300 m above mean sea level. However, the new clones developed by the RRISL, particularly RRIC 102, with leaves which mature rapidly after wintering, and a cuticle, thicker than PB 86, can be planted successfully at higher elevations like Gampola and the lower reaches of Badulla District (Fernando, personal communication).

Phytophthora leaf disease

The most important factors that led to the recommendation made by the RRISL that Phytophthora leaf disease does not warrant the use of control methods under Sri Lankan conditions were: (a) the causal fungus sporulates mainly on rubber pods and pod set can be reduced by a reduction in the intensity of Oidium leaf disease control (b) the weather conditions in Sri Lanka during the rubber seeding season, with bright, hot, sunny days occurring between the rainy spells, were not conducive to the development of Phytophthora leaf disease epidemics (c) the loss of a few leaves from the rubber tree, due to Phytophthora infection, did not cause any deleterious effects on yield; as most rubber trees produced an excess of leaves (Peries et al, 1964; Liyanage, 1976). These simple pieces of information were put together and the RRISL advised all rubber growers, as far back as 1963 that the damage caused by this disease did not warrant the adoption of control measures. This recommendation has saved the rubber growing industry millions of rupees, and, in fact, the industry would not have been viable in this country, if this disease had to be controlled by the use of copper fungicides.

Gloeosporium leaf disease

This disease is of minor importance in Sri Lanka, compared to its considerable importance in Malaysia. It causes occasional concern in wet years in both immature rubber and mature rubber, the latter only immediately after refoliation. The damage done to mature trees is often limited; as the loss of a few leaves from the large number set after wintering is of no consequence. However, the loss of a whole whorl of new leaves from an immature plant, can cause concern. Many of the new

RRIC clones, particularly RRIC 102, are tolerant to Gloeosporium leaf disease, and as these clones are now being recommended for planting almost exclusively in the replanted areas, the damage done by this disease can be expected to tail off in the future.

DISCUSSION

The results of long years of studies, which have been summarised here, in a simplified form, show that biological methods of disease control can be developed for many crops, by careful study of the biology of the fungal pathogens and the host plant. Often, control of diseases is based on simple observations of day to day growth of the host and pathogen and their interaction with each other. The example of the control of Phytophthora leaf and bark diseases is important here. The effect one disease has on the incidence of another, several months later, is interesting.

The control of white root disease of rubber by purely biological means is one of the most important developments in plant disease control achieved by the RRISL. This shows that critical developments in science can be made by local scientists by conscientious effort. We trust that this will encourage more research workers to expend their efforts in this country, to produce satisfying results both for themselves and their own land.

The work described here also shows the value of research to an industry. The rubber industry would have found the economics of production untenable had the many diseases now being controlled by biological means to be controlled chemically.

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BIOLOGICAL CONTROL OF PADDY PESTS IN SRI LANKA

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The need for pest control arose with the beginnings of agriculture. Even in ancient times some biological methods were practised, such as the plant-derived chemicals and insect predators used to regulate pests in China (Flint and van den Bosch 1981). In Sri Lanka, the need for biological control of paddy pests is felt chiefly due to the following problems arising out of control measures adopted currently.

Direct chemical control has led to certain drawbacks such as increasing resistance to insecticides by rice pests, destruction of useful natural insect fauna and unnecessary contamination leading to health hazards.

The concentration of the present rice breeding programme towards high yielding rice varieties has resulted in the replacement of a wide range of indigenous rice cultivars with a few high yielding rice varieties, thus narrowing the genetic basis of resistance, and increasing susceptibility to rice pests.

Improvement of fertilizer and irrigation practices, regardless of ecological interactions with other aspects of the rice crop, has made the rice crop more suitable for pest build-up.

Introduction of short age varieties and staggered cultivation have ensured pests with a continuing habitat for regular build up of populations.

INSECT PESTS OF THE RICE CROP

At present the insect pests of irrigated rice in Sri Lanka could be listed as major and occasional as follows.

Major Pests:

1. The yellow stemborer, Tryporyza incertulas (Walker)
2. The leaf folder, Cnaphalocrocis medinalis Guenee
3. The paddy gall midge, Oiseolia oryzae (Wood-Mason)
4. The brown planthopper, Nilaparvata lugens (Stal)
5. The rice leafhopper complex:
Nephotettix virescens (Distant)
Nephotettix nigropictus (Stal)
Nephotettix impicticeps Ishihara
Tettigella spectra (Distant)
Inazuma dorsalis (Motschulsky)
6. The rice thrip, Baliothrips biformis (Bagn.)
7. The paddy bug, Leptocoris varicornis Fabricius

Occasional Pests:

1. The stemfly, Atherigona exigua Steiner
2. The whorl maggot, Hydrellia sp.
3. The case bearer, Nymphula depunctalis Guenee
4. The leaf eating caterpillar complex: Spodoptera mauritia Boisduval
Borolia venalba Moore
5. Paddy black bug, Scotinophora lurida Burmeister.

THE PRESENT CONTROL PROGRAMME: HOW IT RELATES TO BIOLOGICAL CONTROL

To consider how the present control programme of paddy pests in Sri Lanka may be extended to include biological control, the following factors are relevant.

1. The availability of knowledge and information on major rice pests.

a) Taxonomy: Information on this aspect is fairly well established and at present work on such aspects as the biotypes of O. oryzae and N. lugens is being conducted.

b) General biology: The knowledge presently available is of a satisfactory standard.

2. Forecasting systems and Economic Injury Levels:

a) There is no established forecasting system for rice pests in Sri Lanka at present. Though light trap surveys are being conducted, this is only at a preliminary level and the data available have not been integrated into a definite forecasting system. Some initial work utilizing pheromone traps is being carried out for the leaf folder, C. medinalis on an experimental basis.

No regular field assessment is being carried out and Economic Injury Levels have not been calculated. An exception is the field survey carried out during brown planthopper outbreaks to establish threshold levels.

SURVEY OF NATURAL ENEMIES

Yellow Stem Borer, Tryporyza incertulas

The yellow stem borer is a serious rice pest in Sri Lanka. It occurs at all stages of growth and is found in all types of the rice crop -- lowland, deepwater, floating and upland. It causes extensive damage and exhibits two kinds of symptoms:

i) dead heart: During vegetative growth stage, stem borer larvae bore into and feed in the leaf sheath, preventing formation of panicles:

ii) white head: Growing plant parts are severed after panicle initiation.

Fernando (1967) reported the following egg parasites in Sri Lanka: two Eulophidae, Tetrastichus schoenobii Fieriere and Tetrastichus israeli Mani and Kurian, one Scellionidae, Telenomus dignus Gahan, and an unidentified species of Trichogramma. T. israeli is rare and at best parasitizes 2% of the second brood of T. incertulas egg masses. Parasitization by T. schoenobii may be as much as 10% in the second brood of egg masses.

T. dignus is the most important egg parasite of T. incertulas in Sri Lanka, being an excellent searcher, and is responsible for approximately 85% parasitization in second brood egg masses, though concomitant loss of crop by T. incertulas to the extent of 20% has been sustained.

Rajapakse and Kulasekera (1980) also reported the following egg parasites of T. incertulas: Trichogramma minutum Riley, T. schoenobii, T. israeli and T. dignus. T. dignus was found on more than 65% of egg masses. Combined parasitization rates averaged 88% (range 77-99%) and were 71% in Dinipitiya, 81% in Matara, 81% in Ambalantota, 86% in Kamburupitiya and 97% in Kekanadura.

Larval parasites of T. incertulas recorded in Sri Lanka are three species of Braconidae: Apanteles flavipes Cameron, Apanteles schoenobii Wilkinson and Shirkia schoenobii Vierreck (dorsalis Matsumura), one Eulophidae, Aprotocetus sp. and an Ichneumonidae, Isocima sp. (Fernando 1967). Parasitization by these parasites, in general, is extremely low and no survey or evaluation of the relative importance of the parasites has yet been done.

Introduction of Telenomus beneficus Zehntner and a number of larval parasites may hold promise for control of T. incertulas.

Leaf folder, Cnaphalacrocis medinalis. The damage to the paddy plant is caused by the caterpillar which folds the leaf blade into tubular structures and feeds on the green leaf tissues within these structures. Usually only one caterpillar is found within each fold.

Rajapakse and Kulasekera (1982) reported the following parasites of C. medinalis in Sri Lanka, in and around the southern town of Matara: three Braconidae, Apanteles ruficus (Haliday), Apanteles flavipes (Cameron) and Microbracon hebetor Say, one Elasmidae, Elasmus sp. and a Tachinidae (Diptera), Bactromyia franssoni Bar. Parasitization rates were 38% in Denipitiya, 48% in Kamburupitiya, 53% in Matara, 60% in Hakmana and 70% in Malpana.

Paddy Gall Midge, Orseolia oryzae

The paddy gall midge is a major pest of paddy in the wet zone of Sri Lanka and in certain parts of the dry zone. In these areas about 10% of the tillers of the paddy crop are affected by this pest. Prolonged periods of overcast skies coupled with light to moderate rains favour heavy crop infestation by this pest. Under such conditions of high humidity, up to 40% of the tillers of the paddy shoots have shown silver shoots. The pest attacks seedling paddy. Only on rare occasion does it attack mature paddy. O. oryzae produces no silver shoots on mature paddy, but causes the last emerging leaf to become undersized and transversely crumpled.

Very little information is available in Sri Lanka on the population fluctuation of O. oryzae in paddy fields. The first appearance of silver shoots in the fields is still the only indication of the presence of this pest.

Two hymenopteran parasites Platygaster oryzae Mani (Scelionidae) and Dinarmus sp. (Pteromalidae) and two predators, the carabid, Casnoidea interstitialis and the reduviid Nabis capsiformis Germar have been observed to exert a low degree of natural control of O. oryzae in the field (Fernando 1967). The parasites have been observed emerging from the pupae of O. oryzae. C. interstitialis feeds on the pupae of O. oryzae inside the galls while N. capsiformis attacks the adults.

Brown Planthopper, Nilaparvata lugens

The brown planthopper is one of the most destructive pests of the rice crop in Sri Lanka. It was first recorded as a pest of rice under the name Nilaparvata greeni (Distant) in Kalutara district in 1912 (Fernando et al. 1979). Since then sporadic outbreaks have occurred in several areas, mainly in southwestern Sri Lanka. In the last two decades, it has been appearing in large numbers in several districts, especially in Amparai and Batticaloa, and occasionally causing hopperburn -- a drying up of plants in large patches (Fernando 1975; Dyck and Thomas 1979).

Parasitism has generally been recognized as causing less brown planthopper mortality than predation. Most parasites of the brown

planthopper are low and appear to have limited value for checking planthopper population. However such a limitation may be overcome by the combined effects of several parasites that attack sequentially during the development of pest insect outbreaks.

Parasitization of this pest in Amparai district is caused mainly by Strepsiptera, but parasitization is generally low, according to Otake et al (1976). They observed the following predators in Amparai district: spiders, the Carabid Casnoidea interstitialis, two species of Coccinellids, an assassin bug (Reduviid) and Cryptorhinus sp. (a Mirid). They also reported high parasitic activities by Elenchidae, Dryinidae, Pipunculidae and nematodes in Kandy district. But these were sporadic and afforded no effective control.

Rajendram (1982) collected an Anthocorid, the Mirid Cryptorhinus lividipennis Reuter and two Coccinellids in the paddy fields of Amparai and Batticaloa districts, Pseudogonotopus sp. (Dryinidae) in Batticaloa district and Mymarids and Trichogrammatids, parasitizing eggs of N. lugens, in Kandy district.

In the northern province, Rajendram and Devarajah collected C. lividipennis from Paranthan Kalmadu and Jaffna (Rajendram 1982). Studies have indicated C. lividipennis to be an effective predator of N. lugens (Devarajah and Rajendram 1982). It was possible to mass culture C. lividipennis successfully in the laboratory with a view to releasing it in the rice fields (Devarajah and Rajendram 1981). However, sampling of paddy fields in Karadianaru (Rajendram and Devarajah 1981), Kilinochchi and Jaffna (Rajendram 1982) over a 2 year period did not reveal any appreciable population in these locations.

Leafhopper complex: Nephotettix virescens
Nephotettix nigropictus
Nephotettix impicticeps
Tettigella spectra
Inazuma dorsalis

Santa et al (1973) reported that the most prevalent leafhopper species were N. virescens and N. nigropictus in paddy fields in Kandy district, comprising as much as 37.2% of the insect population.

These were observed to increase very gradually till the heading stage of the crop, and sharply after the heading stage. Occasionally, Nephotettix sp. peak population was noted before maximum tillering. They also reported parasitization of adults and nymphs by Dorilas sp. up to 8.1%. Since increase in parasite population was observed when crop is heading than at two weeks after transplanting, the lowering of the pest population may be due to high parasitic activity. Hence pest epidemic may be avoided by an increasing population of natural enemies. The predator C. lividipennis was observed to comprise 25% and spiders 4.1% of the insect population.

Devarajah (1983) reported the following general predators in paddy fields, during a 2 year survey: the Coccinellids Adalia indica and Coccinella octomaculata and the Odonata Lestes sp., and Pseudagrion sp. in Karadianaru, Kilinochchi and Jaffna and Orthetrum sp. and Anax sp. in Karadianaru and Kilinochchi.

The present survey indicates the presence of endemic parasites and predators that could be manipulated in biological control of pests of the rice crop. Where the local stock of natural enemies is inadequate to achieve satisfactory biological control, these can be supplemented with introduced exotic natural enemies.

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