Our Ancient Methods of Pest Control

Amal Udawatta

Sri Lankan agriculture, which is over two thousand years old was the main livelihood of the people as well as the main source of income for the country. Although the appropriate crops were selected according to their wish by farmers who engaged in the cultivation of a variety of crops, they had to struggle hard to control the diseases which afflicted these crops and to protect them from pestilences.

Although artificial agrochemicals are used by farmers today for pest control, in the olden days, rituals and other traditional methods which successfully controlled pestilences without causing damage to the environment were used resulting in a wholesome and bountiful harvest.

The time is now opportune to examine whether the methods used for pest control in the past were more effective than those used at present. It is quite evident that physical elements such as light, heat and sound were used in the past, for pest control.

Torches prepared by wrapping rags dipped in **"Mee" (Madhuca)** **"Kohomba" (Margosa)** or **coconut** oil at the end of a stick were planted on the embankment on either side of the water course or stream which carries water through the field, positioned to stand across the water and were lit. In the night, the farmers gather together and walk up and down in every section of the paddy field clapping hands or making some such noise. Insect pests disturbed by this noise rise up into the air and are attracted by the light from the torches and eventually are burnt to death by the heat from the flames.

This method known as a **"light trap"** is used by many rural farmers even today. The torches lit for this purpose do not cause any damage to the environment and the pests are also controlled successfully.

Maturing

As the paddy seeds mature they acquire a milky taste. They are very much prone to damage by rats. The farmer struggles hard to save the paddy from rats that attack the entire plant. To prevent the damage caused to the paddy in this way, the farmer chops up the raw fruit of papaw ***(Carica papaya)*** into pieces and scatters the pieces all over the paddy field. Rats who come to attack the paddy bite into these pieces of raw papaw and the sap or latex on the pieces of raw papaw injure their gums and their mouths become sore. The rats find it difficult to munch the paddy with their sore mouths and go away. By the time the rats return with their mouths healed, the paddy is already harvested. In this way the farmers at that time were able to get a full harvest without mortally harming the rats and with minimum damage to the environment.

The Winnow Method or `Kulugaema'

"Kulugaema" is a method used to control insects which fly around during day time. The mucilage **(koholle)** from jak fruit is applied on the back of the winnowing basket which is used to winnow rice and it is slowly dragged across maturing paddy. The air is disturbed by the movement of the winnow causing the insects resting on the paddy to come out. While flying out they get stuck on to the mucilage at the back of the winnowing basket.

The farmers carry out this operation about twice a day, when the mature paddy is close to sprout into ears.

The farmers also place sporadically in the paddy field the stalks of coconut branches, with their wider end turned up, to encourage the birds that fly about in the field to rest on them. Birds resting on these upturned coconut stems spot and prey on the flying insects. This too is a very simple method used by the farmer to control insects.

`Water Ghost' (diya holmana)

A piece of bamboo about 02 segments long is placed at the spot where water flows down from one bed of rice to the one below, and a stone is placed underneath. At the sight of the bamboo stick which rises and falls as the water flows, animals which come to water in the stream are frightened and they keep away. By this method which is known as **"Diya holmana"** the farmer was able to protect the paddy from beasts.

An arrangement made by fixing on a palmyrah branch a nail which would strike against a bottle or a tin when the wind blows, was a commonly used method of chasing away the birds which come to feed on the crop. This was called the"wind ghost" **(hoolang holmana)** by farmers. The intention of the farmer in using such methods was to improve the harvest while at the same time, protecting the environment.

Biological Control

Controlling the growth of a plant or animal species, or destroying a species by using another living species, is known as biological control. This is a successful method which is less harmful to the environment than the destruction of pests by the use of chemical pesticides. This involves the seeking of the natural enemies of pests and using them to destroy the pest concerned. These enemies could either be a mutant, a parasite or a pathogen of the pest. The pest is controlled when it becomes the victim of the parasite at a certain phase of its life cycle. The parasite causes diseases to the pest. When the disease aggravates, the pest dies. In this way, the pest is destroyed. Microorganisms such as fungi, bacteria and viruses are often used as pathogens for pest control.

Small fish such as ***Barbus uneya*** (thiththaya) and ***Aptocheitus dayi*** (irinala handaya) as well as the frog and the monitor, can be named as most suitable mutants for pest control.

The white fungus called ***Nomureae releyi*** is used to control insects such as the rice caterpillar, **(*Spodeptera mauritia*)** and the pink stem borer ***(Sesamia infereus)*** while the fungus known as ***Mettarhihzinm anisopliae*** is used to destroy rice Pentatoid bug (***Seotinophera lurida***). The micro organism with the scientific name ***Euboralia stalli*** feeds on rice caterpillars which attack the paddy.

The "mee" Tree (*Madhuca longifolia*)

The ancient farmers grew the madhuca or `mee'tree on the borders of paddy field and in bare areas in the middle of the fields. When the madhuca trees are in bloom, the fragrance from the flowers waft in the air. The bees and birds which are attracted by the sweet smell of the flowers, help in the control of insect pests. The migration of bees and birds also cause pollination improve the yield.

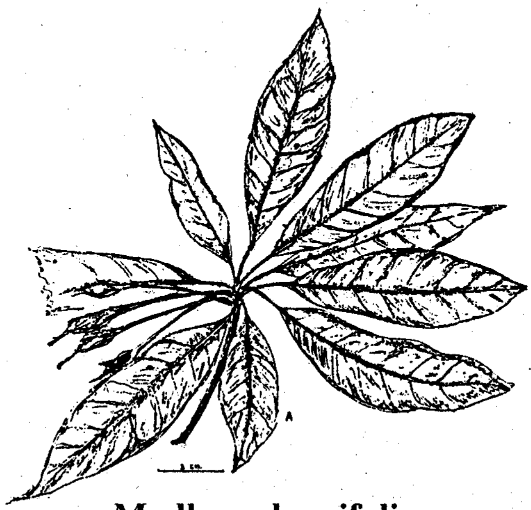
A ritual performed by farmers using "light traps" for the protection of the crop is the lighting of torches prepared by dipping old robes of Buddhist monks in madhuca oil or resinous oil for ola leaf and planting them at random in the paddy filed.

Also the poonac left over from the preparation of madhuca oil was mixed with frankinscence and mucilage from the *Canarium zylanicum* (kekuna) and burnt as incense at the four corners of the field and lamps were lit with madhuca oil to chase away the insect pests.

The farmers buried the roots of the *Madhuca longifolia* randomly in the field and also across the water in the water course which runs across the field. The madhuca roots rot and the essences are mixed with the water. These essences mixed with the water destroy the insect larvae and pupae. Through his familiarity with nature the farmers had the knowledge that the essence of the madhuca root was a substance which would help to destroy insect pests but was on the other hand not harmful to the environment. However what modern scientific research has revealed is that the root of the madhuca tree contains a chemical known as saponin which has pesticidal properties.

Insects such as ***Orceolin oryzue*** (gop messa) and ***Atherigona eseigna*** (kandan messa) caused as much damage to paddy in ancient times as they do today. The farmers in those times, did not employ artificial pesticides to control such pests but instead used plants in the environment to achieve this purpose.

Juice obtained by chopping up and crushing plants such as ***Derris scandes*** (Kalawel) ***Lypersion esculentium*** . (thiththa wel) ***Eupholsia antignomum*** (daluk) and leaves of the pineapple plant were sprinkled all over the field and also mixed with the water to control insect pests such as `kandan messa' and `gop messa'.



Madhuca longifolia
The "mee" tree

The paddy crop at the early stages is prone to damage by worms. To protect it from such damage farmers bury leaves of ***Cinnamomum zeylanicum*** (cinnamon)in the soil when preparing the soil for the crop. Farmers often mixed the dried shredded leaf of the ***Croton lexifenio*** (Keppetiya) into the soil.

In ancient times the farmers were aware that pests find certain smells repulsive. Therefore they grew trees such as the ***Cycas citratus*** (madu) in vacant spaces of the paddy field and pests approaching the field were repelled by their smell. The intention of the farmers was to keep the pests away and also to control them to some extent.

Sprinkling of ash

Even today farmers in many areas, hang a cloth bundle of ash on a long stick and beat it with another stick. The ash that come out of the bundle is carried by the wind and scattered over the paddy. The wood ash sprinkled in this way helps to control many insect pests.

The Margosa (Kohomba) tree

The margosa tree which grows well in the dry zone was used by farmers as a pesticide. The extract of the kohomba seeds was a valuable pesticide to ancient farmers. The extract of margosa was used to destroy the brinjal pod borer and ancient farmers used this substance as a pesticide to protect a variety of crops. Furthermore, the margosa tree was grown in home plots and paddy field as the farmers know the medicinal value of the tree as well as its purifying effect on the atmosphere.

Replanting time

Changes made to the period between the replanting and harvesting also have a strong impact on pest control. For instance, if an insect pest is in the habit of laying its eggs on the surface or underside of a leaf it is possible to bring about natural control of the pest by avoiding the time that they lay eggs, when planting. The pest is controlled by the proper time opportunity and place for laying its eggs.

Why are we attracted to artificial agrochemicals which destroy the ecosystem when we have our traditional agricultural methods which have protected our crops and our environment for thousands of years? The use of artificial pesticides will destroy not only the pests that damage the crops, but also organisms which are beneficial to the environment.

Rotation of crops also helps in the control of pests. The pests which are used to a particular crop are destroyed naturally when different crop is planted. This was a method often adopted successfully by ancient farmers for pest control.

Pest Control through water management is also an ancient traditional method adapted in Sri Lanka. Water is allowed to remain in the beds prepared for paddy for 4-5 days. Paddy pests as well as other harmful organisms in the water die due to the stagnation of water. When the water is let out by opening a gap in the ridge, the dead paddy pests as well as other organisms are removed along with the water. This practice is recognized as a successful method by the present day farmers as well as his counter parts in ancient times.

Why are we attracted to artificial agrochemicals which destroy the ecosystem when we have our traditional agricultural methods which have protected our crops and our environment for thousands of years? The use of artificial pesticides will destroy not only the pests that damage the crops, but also organisms which are beneficial to the environment. As the final outcome of this, the fertile soil will turn out to be sterile and the ecological balance will be disrupted and the environment polluted when the soil gets accustomed to the agrochemicals and the useful organisms in the soil are eliminated.

GREEN REVOLUTION AND INTEGRATED PEST MANAGEMENT

Dr. K.K.D.S. Ranaweera
Programme Co-ordinator/Food Science & Technology
Buttala Affilitiated University College

Development of agriculture probably took place between 10000 and 15000 years ago, Agriculture remained the central feature of human society for thousands of years while all human societies still depend on agriculture. In many countries, farming is still the major way of life. Constantly, agricultural techniques, and related systems are being modified with the view to meet the man's demands.

There has been a considerable increase in the effort given to the breeding and selection of food crops since World War II, Much of this has been mounted by developing countries, which had a long tradition of plant breeding. A notable contribution has been made by the International Agricultural Research Centres which have produced wheat, maize and rice varieties that have largely been responsible for the so-called Green Revolution package of seeds of high yielding varieties, agrochemicals and irrigation schemes.

Before the Green Revolution, the traditional agriculture was characterized with the following features;

1. Low yielding indigenous varieties were cultivated.
2. Irrigation methods and technology were simple.
3. One cropping season per year was practised.
4. Pests and diseases in the crop were in an insignificant degree.

Therefore, there was no need to apply intensive pest controlling methods.

In 1960, developed wheat and rice were distributed to developing countries and this event sparked the Green Revolution. Generally speaking, the Green Revolution helped developing countries often threatened by starvation to grow into modern self-sufficient nations. The high yielding varieties introduced in this revolutional programme were highly responsive to fertilizers and irrigation water. But in the absence of these inputs (fertilizer and irrigation water) these varieties perform worse than indigenous ones. Post Green-Revolutional outcomes can be figured out as follows;

1. High-yielding varieties have been improved.
2. Accordingly, irrigational systems have also become more complicated.
3. Several cropping seasons per year were practised.
4. Mineral fertilizers and chemical controlling methods of pests were required to be introduced.

Before we review the pest management problems, we need to have an idea about a pest. The pest is a troublesome animal, plant, microbe or person that reduces the availability and quality of value of resources useful to humans.' Generally speaking, pests destroy or damage man-made products, crop, forests and livestock. In controlling pests, humans often are utilising chemicals called pesticides. **A pesticide is any chemical that kills, controls, drives away or modifies the behaviour of the pest so that it is no longer troublesome. Pesticides are identified by their target organism, such as insecticides, fungicides, herbicides etc.**

Pesticide Action Network (PAN), an international NGO declared twelve pesticides as the most lethal ones in the world. They are also called the **Dirty Dozen**. Later one more pesticide was added to this list and hence the Dirty Dozen really consists of thirteen lethal pesticides (Table 1). In Sri Lanka, five out of these thirteen are being marketed under 22 trade names.

Although unwanted pests harmful to the crop can be destroyed by using pesticides, these compound can also cause another unforeseen problems. Let's judge a fascinating example showing consequences caused by using DDT($(C_6H_4CL)_2$:CH.C.CL_3- dichlorodiphenyl trichloroethane), one of the most effective pesticides applied to kill insects. When this insecticide was widely used in 1940, some flies were not affected as they were resistant to DDT. These flies survived and formed a generation genetically resistant to the insecticide. In the same way mosquitoes too have become resistant to DDT. Likewise, it is estimated that a total of 400 insect species and 50 species of fungi around the world are now resistant to currently used pesticides. But other sad reality of this insecticide was that, DDT cannot be metabolized or chemically broken down into harmless and inactive substances. This **nonbiodegradable** compound that is insoluble in water builds up in the fatty tissues of animals. As it is passed upward along food chains it become concentrated and in larger amounts can kill animals. This increased concentration of chemicals along a food chain is called **biological magnification**. Birds often are affected by pesticides like DDT. This incecticide also causes egg shells to be very thin so the eggs break easily. It may interfere with breeding behaviour. DDT was also found in the blood and fatty tissues of many people. Therefore the use of DDT became a real annoyance for humans themselves and it was banned now. However some companies indifferently respond to this legislation and continue to produce this very insecticide as well as other banned pesticides in large amounts for export to developing countries.

Another group of pesticides that includes parathion, malathion and phosdrin has different ecological effects although they unlike DDT, tend to break down quickly these pesticides affect not only insects but also vertebrates including human before they breakdown. Malathion is a restricted but widely used insecticide in Sri Lanka. Now it is imported only by the Health Department for its antimalarial campaign. But this chemical is available in village agrochemical shops, although the government has banned its use for agricultural purposes. As malathion is cheap, it is used with phosphorous on fruits and vegetables. Phosphorous in malathion gives a very fresh appearance of fruits and vegetables which can attract consumers.

Table 1 . THE DIRTY DOZEN AND USAGE OF ITS SOME MEMBERS IN SRI LANKA

Common name	Usage in Sri Lanka	Trade Name in Sri Lanka	Distributor in Sri Lanka
1. Aldicab	No	-	-
2. Camphecholor	No	-	-
3. Chlordane	Yes	Chordane 40 Dee Bug Makuna	Baur
Heptachlor	No	-	-
4. Chlordimeform	No	-	-
5. DBCP	No	-	-
6. DDT	No	-	-
7. Aldrin	Yes	Aldrin 20 Termite Soil Concentrate	Lankem Finalay-Rentokil Lankem
Dieldrin	Yes	Wood Preservative A Wood Preservative B Dieldrin 20	
Endrin	No	-	-
8. EDB	No	-	-
9. BHC (HCH)	No	-	-
Lindane(&HCH)	Yes	Gammaxéne D 120 Gammalin	CIC
10.Paraquat	Yes	Anglo Asian Paraquat Baur's Paraquat Ceypetco Paraquat Finchem Paraquat Gramoxone Harquat Hychem Paraquat How not in sale Lankem Paraq. Mackwood Paraquat	Anglo Asian Baur Cey/Petroleum Finlay Chem. CIC Harrisons Haychem Lankem Macwoods
11.Ethyl Parathion Methyl Parathion	No	-	-
12.Petachlorphenol	Yes	Candarsan MMA MMB Wood Preservative A Wood Preservative B	Mansons-Mixture Lankem
13. 2,4,5-T	No	-	-

Source: World Health Organization/Sri Lanka Registrar of Pesticides /Sri Lanka Pesticide Association/Friedrich Ebert Stiftung.

No eating, drinking and smoking working areas.

Farmers of the today world face a real dilemma. Their responsibility is a contrast between two necessities; they will have to produce foods sufficient to meet the demand of the increasing population where four million people are born every ten days. On the other hand, pesticide-free foods with no pest damages are the primary interest of today's consumer. Moreover, man is now more concerned about organically farmed crop products which promotes environmental protection.

So how shall we feed the world and how can we make agriculture compatible with sustainable ecological and social development. Sustainable development, in general, encompasses four major points;

1. It links economic development to environmental sustainability.
2. It recognizes a growing interdependence and promotes an integrated approach to interlocking crises. e.g. the relationship between population and consumption.
3. It is mor concerned with long-term development plants than short-term ones.
4. It recognizes a generational responsibility

According to the (World Health Organization) WHO estimates, 2 million pesticide poisoning instances per year are recorded and at least 10,000 people die of immediate pesticide effects. No one knows how much these chemicals contribute to cancer, birth defects, genetic diseases, reproductive failure, and other human health problems. Moreover, many pesticides are know or suspected to be mutagens, carcinogens and cumulative metabolic poisons in low chronic doses.

It is very important to note that, the same organism that may be a pest in one case may be a friend in another. Only about one hundred species of plants and animals cause 90 percent of all damage to foods and crops. But application of pesticides will kill all the natural predators and subsequently upset the ecological balance.

Pests that were not previously a problem begin to grow out of control. As already mentioned, persistent chemicals (such as DDT) are bioaccumulated and biologically magnified in food chains, eventually reaching toxic levels in humans. One of the main threats faced by many endangered species is pesticide poisoning.

It is pertinent to indicate that improved pest management techniques can cut pesticide use between 50 to 90 percent without reducing crop production or suffering diseases. This approach is called integrated pest management (IPM), a flexible, ecologically based pest-control strategy such as predators (wasps, ladybugs, praying mantises) or pathogens (viruses, bacteria, fungi) to control pests safely. IPM is looking at the solution to pest problems in a more comprehensive, economically and ecologically compatible manner. IPM is a pest management system that, in the context of associated environment and the population dynamic of the pest species, utilizes all suitable techniques and methods in as compatible an manner as possible and maintains pest populations at levels below those causing economic injury. It is not simply the combination of two control techniques but the integration of all suitable management techniques with the natural regulating and limiting elements of the environment.

Implementation of IPM programmes requires knowledge of available tactics which can be integrate across disciplines to rescue pest problems with the least expense and damage to the environment. IPM programmes are already in use all over the world on a wide range of crops.

The basis for IPM implementation in our country should be considered from different points of views. Pesticides nearly always affect non-target species along with the intended targets, upsetting the local ecological balance. Pesticides may also affect ecosystems far removed form farmers' fields, through movements in ground and surface water, and in air. Therefore an IPM system should be the primary concern of environmentalists. The shadow price of chemicals may be much greater than the nominal price, due to several layers of subsidy. When environmental costs are included, the total social cost of pesticides may become higher as a result of improper use. In a more rational world, governments and farmers could not afford not to adopt IPM.

Handing and application of chemicals poses health hazards to the poorest sectors of the population, who obtain menial jobs in the agrochemical production/marketing business, and to poor farmers who know nothing about the hazards, or who do not possess the equipment to use chemicals safely, Moreover, in hot climates like Sri Lanka the use of protective clothing is often impractical. Pesticide residues in or on food can pose a serious health hazard to consumers. The addiction of farmers to heavy use of pesticides in conventional agriculture imposes new levels of dependency on the outside world. Community-level initiatives based on local leadership and co-operation have been undermined, creating a feedback effect of greater dependence on external authorities to solve local problems.

The stability of agricultural production which IPM makes possible has important benefits for political stability at the national level. In countries ,where a single crop dominates agriculture, and also where agriculture is the dominante sector of the economy (as in most developing countries), governments can fall if production of the dominant crop is ravaged by pesticide-resistant pests. IPM tends to buffer these effects by maintaining natural controls in the ecosystem.

The International Rice Research Institute (IRRI) defines the main principles and components applied in planning and implementing IPM systems. The goals of these implementations are the following;

1. To understand that the ecosystem is the management unit.
2. To maximize the use of natural enemies.
3. To realize that any control approach may produce undesirable or unexpected effects.
4. To promote an interdisciplinary approach for developing control programmes.

The IPM system should consist of the following major principles;

1. **Identification of pests to be managed in crop production system (agroecosystem).**

   a. Key pests (major disease).
   b. Occasional or secondary pests.
   c. Potential pests.

The main objective of this principle is to allow potentially harmful species to exist below **damage thresholds** (action level). Damage threshold means the disease level at which disease begins to adversely affect yield or quality. **Action threshold** is the severity at which control measures should be determined and applied to prevent an increasing severity level from reaching the damage threshold.

2. **Definition of the management unit the agroecosystem.**

IPM tactics cannot be formulated for pests of particular crop in isolation from the cropping system, or more broadly the agroecosystem, of which the crop community in time and space can have a major influence on pest incidence and on damage to any particular crop species. Wild plants can also be an important part of the agroecosytem as weeds, or indirectly as alternative hosts of pest or of beneficial organisms.

Sustainable yield in the agroecosystem derives from a proper balance of crops, soils, nutrients, sunlight, moisture and coexisting organisms. The agroecosystem is productive and healthy when this balance and rich-growing conditions prevail, and when crop plants remain resilient enough to tolerate stress and adversity.

Usually, an agro-ecologist strives to restore the resiliency and strength of the overall agroecosystem to fight pest, disease or soil deficiency.

If the cause of disease, pests and soil degradation is understood as imbalance, then the goal of the agro-ecological treatment is to recover balance. In agro-ecology, ***biodiversification*** is the primary technique to evoke self-regulation and sustainability.

The optimal behaviour of agro-ecosystems depends on the level of interaction between their biotic and abiotic components. Factors of the agroecosystem such as isolation of growing regions, size of growing area, water availability on length of time of crop production/year, water availability as a factor regulating number of crops/year, ability to synchronize planting, crop turn around time and residue management and potential to conserve natural enemies are of vital importance in suppressing pest population to a considerable level.

a. The agroecosystem should be determined by using the characteristics of local cropping systems and movement or development patterns of key pests involved.

b. The area of fields involved should also be studied.

3. Development of pest management strategy -IPM's general objective is for containment rather than an eradication strategy.

4. Development of reliable monitoring techniques.

a. pest population measurement.
b. amount of disease, damage or loss.
c. monitoring a critical component of IPM.

5. Establishment of economic thresholds.

a. pest population or disease incidence level that produces reduction in crop value greater than cost of implementing a pest management action.

b. economic threshold values vary for a given crop, state of its development and environmental conditions (biological and physical).

6. Evolution of descriptive and productive models.

a. models not required for most simple IPM system.

b. model is a useful tool but must be fulfilled to understand the system.

A successful IPM programme first determines the real pests and those induced by improper application of pesticides. Out of them the "key pest" that cause too much losses on the crop should be separated. Establishment of the realistic thresholds for each pest is of significance. It is also important to identify the factors to control or have the potential for controlling populations of key pests and measure the effects of these factors (e.g. resistant varieties, natural enemies, cultural measures etc.). Control systems designed to control the particular pests may vary according to the area, time (season) and other ecological factors.

Under IPM, there are three concomitant strategies in the evolution of disease control;

1. Cultural control-sanitation,crop rotation, biological control etc.
2. Chemical control.
3. Varietal resistance.

The standard consideration of an IPM programme into the pest problem is that diseases which progress slowly are more easily managed while diseases which progress slowly are more easily managed while diseases which spread extremely rapidly are more difficult to manage. Most satisfactory control has been achieved with prevention of initial attack rather than to slow down a fast moving epidemic. Generally speaking, the purpose of disease control is to prevent disease damage from exceeding a certain level where profit, expected yield or quality is significantly diminished. There are several possible IPM operations and one or few of them can be decided to apply by the IPM programmer considering agronomical, geographical and economical aspects of the given area and the crop/crops to be cultivated.

1. **Cultural methods** - Cultural control is the most stable tactic because pests are less likely to overcome these effects through biotype development.

a. crop rotation - Crop rotation keeps pest population from building up.
Perhaps the most powerful are those controls based on crop patterning in time and space, which in various ways dislocate the life cycle of a wide range of weed, pathogen and insect species.
Various forms of mixed cropping and intercropping also minimize the spread of airborne pathogens and insects. Crop rotation has been the basis for control of soil-borne pathogens, nematodes and some insects, as well as of weeds, for many centuries.

b. destruction of crop residues from the previously cultivated crop. Flooding fields before planting or burning crop residues (and replanting with a cover crop) can suppress both weeds and insect pests. But it should be noted that burning of crop residues can reduces the soil nutrients remarkably.

c. suitable tillage (land preparation)

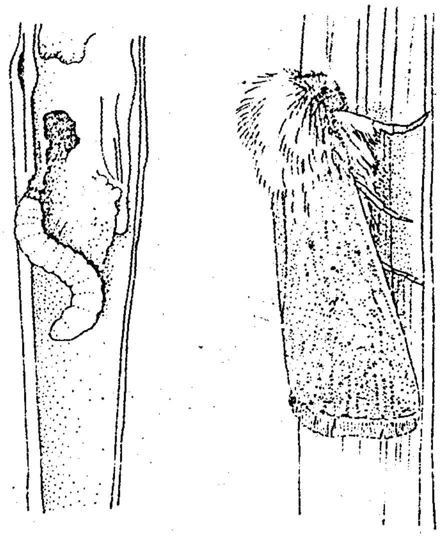
d. variation in time of planting of harvesting

e. fertilizer applications

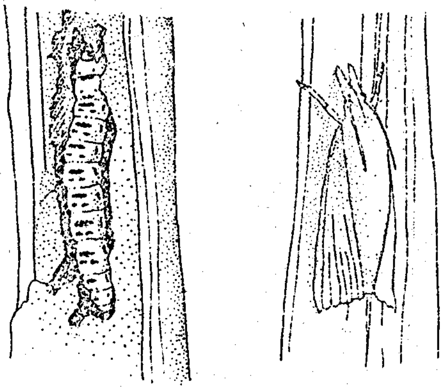
f. sanitation - Home gardeners often plant a border of insect replanting plants, such as garlic or marigolds.

g. water management

h. planting of trap crops - A small area is planted a week or two before the main crop are also useful. This plot matures before the rest of the field and attracts pests a way from other plants. The trap crop then is sprayed heavily with pesticides enough so that no pests are likely to escape. The trap crop is destroyed so that workers will not be exposed to the pesticide and consumers will not be



PINK STALK BORER
(Sesamia calamistis)



SPOTTED STALK BORER
(Chilo paretellus)

at risk. The rest of the field should be mostly free of both pests and pesticides.

I. Early maturing varieties

Cultural control practices have advantages; stability and practices that would normally be done y the farmers anyway.

The disadvantages of cultural control are that it needs a large area (many farmers) to make community level effects work (implies organization of farmers) and it has a risk to yield when modifying practices. But the practices like crop rotation (e.g. creation of rice-free periods in paddy field), sanitation and tillage (crop residue management), weed management, synchronous planting between fields and number of crops/year are effective at the community level.

2. **Mechanical methods**
   a. hand destruction
   b. exclusion by screen or barriers
   c. trapping (suction devices)
   d. crushing

3. **Physical methods**
   a.. heat
   b. cold
   c. humidity
   d. energy-light traps, light regulation
   e. sound

4 **Biological methods** - Biological control is the use of organisms to check pest population. This method retains a more natural, balanced ecosystem and avoids the disadvantages of chemicals. Biological pest control was first used in 1888 when an Australian ladybird beetle was introduced in California to help reduce the members of a small insect pest that was destroying citrus crops. As predators or parasites wasps are specially useful in controlling other

insects. Moreover use of bacteria, virus, fungus and protozoa as agents of biological control is being studied and several products have been already developed. Spores of bacteria that affect certain insects are applied over an area like an insecticide.

Surveys reveal that there are 1,005 plants worldwide that have known insecticidal properties, 384 that are antifeedants, 279 that are repellents, . and 108 that are nematocidal. With information and research, insecticidal farms could be established in each region to supply natural pesticides.

Most if not all, pest problems can be controlled by using natural plant extracts produced by the farmer in nearly every area of the world. Neem tree, ,Kohoba native to India, produces a fruit that contains a seed that can be dried, ground and mixed with water to provide a potent natural pesticide, insect growth regulator and antifeedent. Neem has been shown to have interesting insecticidal properties that are not directly poisonous to insects. It kills them by disrupting their life cycles or by preventing them from reaching adult hood or slowing their feeding. Neem has shown fungicidal and virucidal properties as well. 60% of the weight of the seed remains after the oil has been extracted. This material has been shown to increase yields of many crops when used as an organic fertilizer. It can also control nematodes and root diseases and provides systemic effects for insect control. As far as Neem is easily grown in Sri Lanka our farmers should be encouraged to use it for the good of Agriculture.

Another form of pest control is sterilizing of male insects by radiation. The method whereby insects contribute to their own destruction is called autocidal control. Male insects are first sterilized atmaturityand then released to the ecosystem. Mating of these male insects with female ones results in having eggs that are not fertilized. Scientists suppose that if there are ten times more sterile males than fertile ones in a population, many insects species could be eliminated within four generations.

Predators

For example, predators often are the most important group of biological control organisms in rice; each predator will consume many pests during its lifetime. They are certainly the most conspicuous forms, and are sometimes confused with pests. Predators occur in almost every part of the rice environment. Some such as certain spiders, lady bird beetles, and carabid beetles, search the plants for prey such as leafhoppers, planthoppers, moths, and larvae of stem borers and defoliation caterpillars. Spiders prefer moving prey but some may attack insect eggs. Many species of spiders hunt only at night. Others make webs and collect whatever entered the web through the day and night.

Many beetles, some predatory grasshoppers, and crickets prefer insect eggs. It is not uncommon to find 80-90% of the eggs of certain insect pests consumed by predators. An adult wolf spider may attack and consume 5-15 brown planthoppers each day.

The immature and adult stages of most predators attack insect pests and many prey are required for the development of each predator. Other predators, such as water bugs live on the surface of the water in the rice field and when insect pests such as hoppers, small larvae of stem borers, and leaffolders attempt to disperse, many fall on the water surface and are attacked by water bugs and related predators.

Predators tend to be generalised feeders and often attack other beneficial species when other food is scarce. In general, however, predators feed on those species which occur in greatest abundance such as pests. It is important to realize that a few insect pests occurring at leaves which cause no economic damage are helpful for us since they provide food to maintain populations of beneficial species at levels which can prevent damaging pest outbreaks.

The biological control system includes conservation of natural enemies, augmentation and introduction of natural enemies, and mass production and release of natural enemies. This strategy has several important advantages; it is economical, self perpetuating and safe to apply while extending no environmental hazards.

Appropriate techniques like the application of chemicals only when pest population reaches economic threshold, use more selective chemicals, developing better application methods and use correct formulation can be used to conserve the natural enemies.

Disadvantages of biological control methods can be the following;

a. It does not always maintain pest population below economic threshold.
b. It is easily disrupted by chemicals.
c. Its manipulations is rather difficult.
d. Its rearing and releasing may be expensive.
e. Time required before pests are suppressed.
f. There are problems associated with collecting, shipping rearing, releasing and other biocontrol agents.

Biological control must be integrated with other control measure such as the use of host resistance, cultural, physical and other more economically and environmentally safe disease management practices.

5. **Chemical methods** - Where is no alternative to using a chemical toxin for pest control a single heavy dose of a non persistent pesticide might be applied just at the time that pests are most vulnerable. Some important pesticides are the following;
   a. insecticides
   b. attractants
   c. repellants
   d. sterilants
   e. growth inhabitors

6. **Genetic methods**

   a varietal resistance - For example, in Sri Lanka, our farmers unknowingly have contributed to the resources of genetic resources tremendously. The salt tolerant "Pokkali" is the standard for testing improved salt tolerant rice cultivars.

One strain of *Oryza nivara*, a wild rice found in Sri Lanka has the gene for resistance to grassy stunt spreading through Asia, which has the potential of destroying the staple crop of more than half the world's population.

b. propagation and release of sterile of genetically incompatible pests.

National policies for supporting IPM objectives are of fundamental importance. But we should not forget that, although he government should take the responsibility for controlling certain pests (notably migrant species), in most cases the control of weed, disease, insect and other animal pest problems is the responsibility of the farmer.

7. **Regulatory methods**

a. plant and animal quarantine - Plant and animal species imported from foreign countries should undergo assays to assure that the material are not contaminated by any pathogens, pests or the like.

b. eradication and suppressive programmes - At community level or regional level collaborative programmes should be organized to successfully eradicate pests that exert a threat to the crops of the given area and by and large that of the region.

Our role in this contest

One of the major causes of unsuccessful IPM implementation in developing countries is research that has been too science-based, sometimes with unduly ambitious goals or with ill-defined objectives that may bear little relationship to what is practicable.

IPM should be built upon local indigenous farming knowledge, treating traditional cultivation practices as components of location-specific IPM practices rather than we borrow the knowledge and technology from overseas. A closer look at ethnoscience (the knowledge system of an ethnic group that has originated locally and naturally) has revealed that local people's knowledge about the environment, vegetation, animals and soils can be very useful in this regard.

National policies for supporting IPM objectives are of fundamental importance. But we should not forget that, although the government should take the responsibility for controlling certain pest (notably migrant species), in most cases the control of weed, disease, insect and other animal pest problems is the responsibility of the farmer.

National policies to provide pesticides at favourable prices directly affect the farmer's pesticide-use patterns especially those that are less harmful for humans.

Farmers who cultivate vegetables invest heavily in seeds, fertilizer, water and labour in the anticipation of high returns. Cheap pesticides are well worth the extra cost, in the farmer's view, as a means of insuring his investment. On the other hand one must not forget that farmers select the least-cost mix of pesticides and will use the amounts they believe are warranted given their cost, anticipated production benefits, and the perceived risks of not using adequate amounts. Another result in many developing countries has been an over-reliance on chemical pest control and a drastic overuse of chemical pesticides in crops such as rice and vegetables. Farmers therefore should be educated on this spirit lest they should make mistakes of this nature.

Training of the different groups involved in crop protection is vital to technology transfer and IPM implementation. Training must target the farmers (as the final client group). extension workers, crop protection technical services personnel, researchers, of IPM programmes for many crops are not available. On the other hand this educational and extension training opportunities have no access to the farmers because the majority of farmers in developing countries are illiterate and often poor. But the extension of IPM as a new technology is a matter of human resource development. Statistics revealed that, trained farmers showed more understanding than untrained farmers in their ability to diagnose pest problems, to recognize natural enemies, and to apply thresholds. Moreover, they tend to make fewer pesticide applications. Therefore in the development of IPM training material farmers are needed to involve.

Furthermore, the role of Ngos and of farmers themselves in providing training should be encouraged. The influence of the agrochemical industry is also a major factor to contend with in government efforts to implement IPM. Key decision-makers are needed to convince the potential benefits as well as the implementation of IPM in different sectors. As well, our Universities are now teaching the IPM concept, and it may significantly affect the direction of plant protection in near future. It is also very vital to have a common scence on IPM projects held by the individual farmers as well as government agencies responsible for different aspects of national IPM programmes with a view to effectively implement IPM programmes islandwide.

INTEGRATED PEST MANAGEMENT AND THE FUTURE OF INSECTICIDES

M.M.S.C. KARUNARATNE
Senior Lecturer
Department of Zoology
University of Sri Jayewardenepura

The history of pest control in the twentieth century clearly shows, that our present pest problems arise from the exclusive reliance on one control method, the use of pesticides.

Ever since man has changed the natural environment for systematized agriculture, cultivated crops have been subjected to attacks by various pests and diseases. These included insect and other invertebrate pests, pathogens such as viruses, bacteria and fungi as well as many weed pests. As long as they remained in small numbers, the damage caused was negligible.

Once man realized the necessity of increasing food production to cater to the needs of rapidly expanding populations, he started on intensifying the agricultural output. This resulted in a drastic disturbance of the 'natural balance' in the environment. With new agricultural technologies, man was able to enhance crop production. But at the same time they tend to increase pest problems by making the crop environment most favourable for the rapid increase of pest populations.

It is true that in the early days, before the discovery of organic insecticides, man has used rather simple chemicals such as kerosene, arsenic compounds, sulphur etc. and some compounds derived from plants such as nicotine and pyrethrum to control pests. But these chemicals were not very effective and they were not applied in large scale. Also, the technology used for their application was not very advanced and there was emphasis on traditional agricultural practices.

However, since the development of modern insecticides after World War II, farmers stopped using these cultural practices. They placed almost exclusive reliance on the new toxic chemicals. In the farmers' point of view, the results gained by the use of insecticides were most spectacular, as they were capable of killing a broad range of pests in vast numbers using small doses. At the same time more efficient pest control was achieved by improved spraying methods, controlled irrigation, improved artificial fertilizers and systematic use of herbicides. Suddenly farmer found that pest control was so easy and spraying insecticides became the universal answer to all pest problems.

Consequences of the Use of Insecticides

There is no doubt that, from the stand point of human welfare insecticides have been a great benefit to mankind. But as is often the case, this has been a mixed blessing, as serious problems have arisen to detract from the benefit gained from these poisonous chemicals.Without any doubt the use of pesticides has been a major cause for several environmental problems we have to face today.

Also, many insecticides leave residues on or in crops, in soil or flow into streams, rivers and other water bodies and cause serious hazards to man and animals. It has been found that substantial amounts of these residues may persist in the body tissue of man and other organism for years. This may cause cancer, sterility, birth defects and many other health hazards.

Insecticides are poisonous to a large number of animals such as pollinators, wild life and nature enemies of pests apart from the target species. Also, pests may recover from the action of pesticides and their populations may arise to extremely higher levels than before. Furthermore, other non-target species may increase in number and become serious pests following insecticide applications. This was the case with some tea pests in Sri Lanka. The use of DDT to control the shot hole borer which is a serious tea pest, ***(Xyleborus fornicatus)*** has led to the emergence of the mites in tea plantations to economic pest levels.

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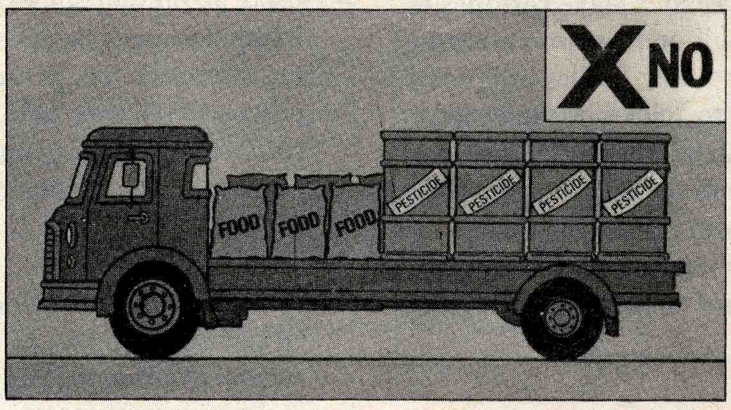
Apart from the above, a very serious problem created by the use of insecticides is the development of pesticide resistance in pest species. As we already know, mosquitoes and house flies have developed resistance to DDT and some other insecticides. In Sri Lanka, the use of DDT to control mosquitoes had to be discontinued due to their resistance to it. Even though more powerful insecticide malathion is being used at present, there is a suspicion that mosquitoes may be developing resistance to this insecticide too. It seems likely that most pests and vectors will eventually develop resistance to most insecticides if these chemicals are continuously used against them.

According to the Food and Agricultural Organization (FAO) of United Nations, the number of arthropod pest species resistant to various insecticides have reached up to 392 in 1980. The World Health Organization (WHO) in 1980, has listed 136 species of public health vectors as resistant. This includes 47 species of Anopheles resistant to dieldrin, 34 to DDT and 10 to malathion. Also there are 42 species of Colicine mosquitoes that have developed insecticide resistance.

The export of insecticides to the developing countries from the developed has been increasing dramatically over the past few decades. In Sri Lanka, at least 117 of these chemicals in various formulations are freely available in the local market. As they are used in agriculture and public health programmes frequently without any discrimination, many direct risks are bound to arise. According to WHO, there are more than 500,000 poisonings and 5,000 deaths that can be directly attributed to pesticide use each year in developing countries. In Sri Lanka, it is reported that an average of about 13,000 people are acutely poisoned by insecticides. Also as described before, the majority of these chemicals are of high mammalian toxicity presenting serious risks to man, other organisms and to the environment. There is clearly an urgent need for bringing in insecticides in a suitable manner into integrated pest management systems.



Pesticides must not be loaded on the same vehicle as foodstuffs.

Integrated Pest Management Concept

We have already experienced how insecticides can cause havoc to human life and to the environment. It has now become absolutely necessary to look for a fresh approach to pest control. Also, this should be based on a biological and ecological understanding. It is clear that we must combine all control methods, whether they are chemical, biological or cultural in a environment compatible manner, so as to maintain pest populations below the economic injury level and at the same time cause the least possible disruption to the ecology. This is the basic concept of integrated pest management.

For successful pest management, a good understanding of the biological system of which the pests are a part is very essential. Also the most important aspect the farmer has to be made aware of is, that a pest does not necessarily have to be eradicated in order to be economically controlled.

Future of Insecticides

As we know well, insecticides are highly toxic chemicals, They offer a quick and immediate solution to our pest problems. They are highly effective and economical to use. Also they can quickly be marshaled especially in large areas to arrest pest damage immediately. It is quite obvious that pesticides are a powerful tool in insect pest control and definitely will continue to play a major role in pest management programmes. But the critical question was, how best can we use insecticides to obtain their maximum benefit, while at the same time minimizing their adverse effects.

Integrated pest management does not advocate a total ban on the use of insecticides. Neither does it place insecticide use as the central feature of pest management. It rather allows the use of these chemical in a compatible way with other control methods.

Whenever possible, pesticides must be integrated with other control methods. This should be done in such a way that there is minimal disruption to the ecosystem. Also pesticides must be used in a minimal quantity and only when the need to use them is clearly established. As very few insecticides are selective, the mortality of non-target organisms may be minimized by using appropriate formulations and application techniques. Furthermore, pesticides must never be used as routine, prophylactic treatment in agro-ecosystems. Also they must be used only after the prevailing

Unfortunately, developing countries like Sri Lanka have to face some major difficulties in developing well-coordinated integrated management schemes for pests. One such difficulty is the general ignorance of the details of biology, ecology and behavioural patterns of most pests and their natural enemies. Also in countries like ours, there is a shortage of trained people to provide the necessary research and other services needed for an effective pest management.

Finally, most developing countries do not have enough, well co-ordinated organizations and institutions for dealing with major pest problems. Because of inadequacies such as these, their reliance on insecticide use is extremely high. Hopefully with the development of relevant research on insect pests and vectors, there will be less dependence on insecticides alone and more utilization of integrated control in future.

The farmers sprayed the pesticides from airplanes. These poisons killed the insect pests, and the farmers' crops were saved. But using poisons raises many questions.

INSECT PEST CONTROL ; THE SEMIOCHEMICAL APPROACH

DR. N.E. GUNAWARDENA
Department of Chemistry,
University of Kelaniya

INSECT'S RECOGNITION OF ODORS;

Have you ever seen a female brinjal fruit borer (*Leucinoides orbonalis*) laying eggs on a coconut palm or the reverse, a female red weevil (*Rhynchophorus ferrugineus*) laying eggs on a brinjal plant? The answer is no because insects have a remarkable ability to recognize their respective hosts. They also have ways of communicating with other members of their own species as well as other species.

In 1959 a German scientist A.R. Butenendt isolated and identified an alcohol, 10(E), 12(Z)-hexadecadienol which is emitted by the body of the female silk moth, ***Bombyx mori*** to signal the male ***Bombyx mori*** of her availability for mating. This finding opened up a new chapter on insect communication in the broad area of chemical ecology. More than 1000 such chemicals responsible for interactions between insects and insects/insects and plants have been revealed up to date. The chemicals that carry messages from one organism to another are given the term Semiochemicals meaning, Signal Chemical (Greek semeon=signal). The host finding behaviours of some Coleopterans, mate finding behaviours of Lepidopterans, trail following action of ants, mass attack by ants if you disturb their nest, all organized activities in a beehive are due to the semiochemicals (**Fig 1**).

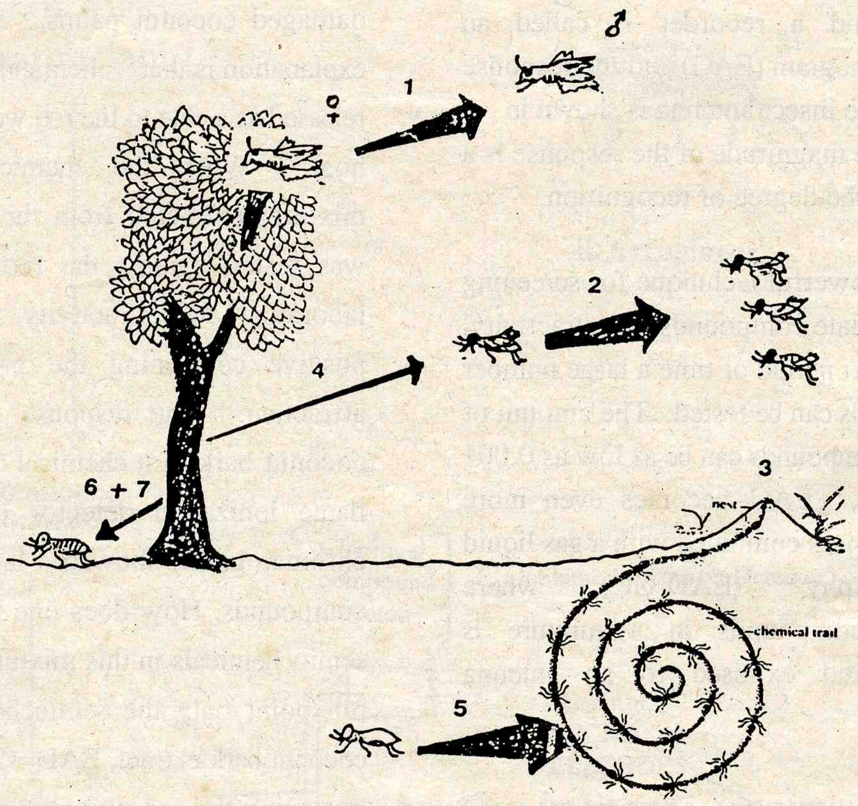
Insects recognize semiochemicals mainly through their antennae. Insect antennae are very powerful detectors which detect compounds at levels even as low as 10^{-10} (picograms) in contrast to some chemical detectors in a modern laboratory, e.g. capillary column Gas Liquid Chromatography, (GLC) which could record chemicals only at 10^{-9} (nano gram) level.

An insect antenna has a large number of olfactory hairs where the receptor cells are located. When semiochemical molecules from the air bind to the receptor cells it creates a flow of ions across the membrane causing a change in the membrane potential. This is called slow receptor potential and is composed by many elementary potentials. The slow receptor potential is transformed to action potentials (nerve impulse) which finally are transposed into the central nervous system resulting in a specific behaviours such as flying towards the host or mate, trail following etc.

MEASUREMENT OF RECOGNITION; ELECTROANTENNOGRAPHY

In 1957 D. Schneider another German scientist found that the sum of slow receptor potentials created in an antenna on receipt of a semiochemical can be measured by inserting two micro electrodes into the two ends of an insect antenna.

FIG 1



INTRA SPECIFIC COMMUNICATION

1. Sex Pheromones
2. Aggregation Pheromone
3. Trail Pheromone

SEMIO CHEMICALS

INTER SPECIFIC COMMUNICATION

4. Host Attractants
5. Defence Secretions
6. Repellents
7. Deterrents

Since the potential differences created are very small being in the range of 0.1 to 1.5 mV in magnitude, an amplification is necessary before recording them. A simple device comprising two microelectrodes, an amplifier and a recorder is called an electroantennogram (EAG) and the response pattern of the insect antenna is shown in **Fig. 2**. The magnitude of the response is a measure of the degree of recognition.

EAG is a powerful technique for screening single candidate compounds for attractivity. Within a short period of time a large number of compounds can be tested. The amount of candidate compounds can be as low as 0.001 micro gram. EAG becomes even more useful when it is combined with a gas liquid chromatography (EAD-GC) where individual compounds in a mixture is separated and exposed to an antenna sequentially.

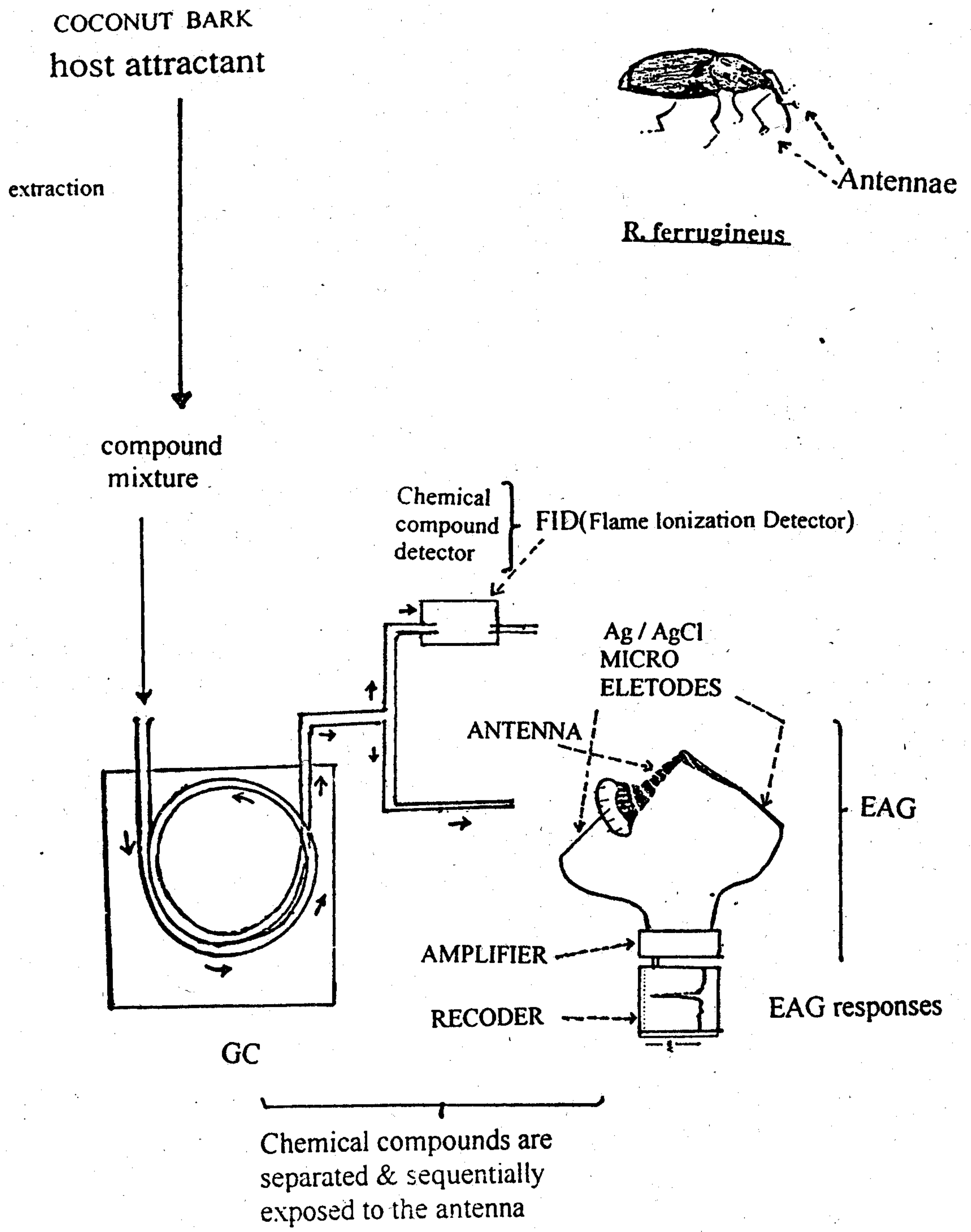
THE SEMIOCHEMICAL APPROACH TO CONTROL INSECT PESTS;

To illustrate the semiochemical approach, the case of the coconut pest, Rhynchophorus ferrugineus commonly known as the red weevils can be considered. The red weevil is one of the major pests of coconut palm. The female red weevil lay about 200 eggs on an open tissues (a wound) of the coconut bark and the larvae feed on the soft tissues of the palm until they complete their growth which take 4-6 months. This cause damage to the palm and finally it dies. Since the larvae are inside the palm it is difficult to detect this pest before the damage become serious.

In the semiochemical approach one looks for possible clue of the target insect's communication modes. In this case it was known that the red weevil is attracted to damaged coconut palms. Most plausible explanation is that a chemical signal may be released as a clue to the red weevil to find its host. When the chemical compound mixtures extracted from the coconut bark was tested against the red weevils in a laboratory for attractivity, it was found positive confirming the presence of an attractant. The response profile of the coconut bark to a chemical detector called flame ionization detector (FID) (**Fig 3**, chromatogram) showed a large number of compounds. How does one recognizes the semiochemicals in this mixture? In order to pin point only the semiochemicals in the coconut bark extract, EAD=GC was carried out using the red weevils antenna (**Fig 2**). The bark extract was separated into its components by the GC and they were sequentially & simultaneously exposed to an FID and a red weevil antenna. The red weevil antennal response profiled (EAD-GCs) showed the recognition of compounds exposed to the antenna at 39.00 min. Chemical identification of the two compounds fell into this active region showed r-nonanoic acid lactone (1) and 4-hydroxy-3-methozystyrene (2) as attractants.

The next step was to produce these chemicals in sufficient quantities synthetically because from coconut several

FIG 2.


COCONUT BARK
host attractant
extraction
compound
mixture
Antennae
R. ferrugineus
Chemical
compound
detector
FID(Flame Ionization Detector)
Ag / AgCl
MICRO
ELETODES
ANTENNA
EAG
AMPLIFIER
RECODER
EAG responses
GC
Chemical compounds are
separated & sequentially
exposed to the antenna

EAD-GC

kilos of the coconut bark one can isolate only micro gram quantities of above attractants. Artificially produced attractants can be used in a trap as a bait to attract the red weevil. The red weevils which lure into the attractants will get trapped & die.

THE ADVANTAGES

Semiochemical baited traps can be deployed to reduce adult pest population thus reducing the pest attacks on palms.

An attractant baited trap can be used to monitor pest levels too. The trap catch will be indicative of the level of pest population and preventive measures such as sealing the wounds of the bark can be attended to if necessary.

The conventional method of control of this pest is drilling holes in the bark of a infested palm and introducing several kilos of insecticides to kill the larvae inside.

The attractant baited trap is completely free of insecticides and therefore this method is environmentally safe.

Insecticides are not selective for a particular pest species thus killing beneficial insects species as well as pest species. Semiochemical approach only destroys a target species because the attractants are species specific.

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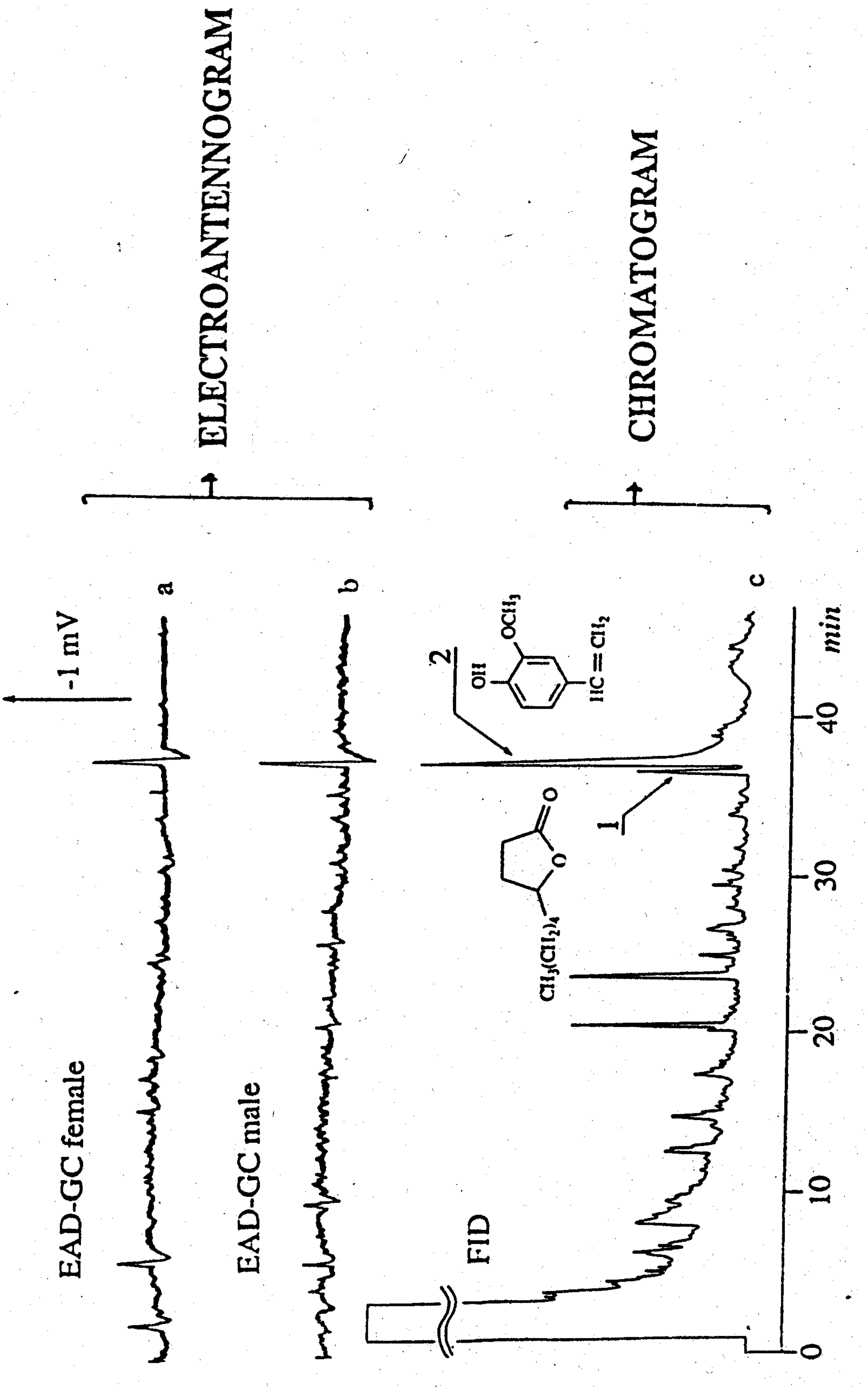
ELECTROANTENNOGRAM
CHROMATOGRAM
EAD-GC female
EAD-GC male
FID
-1 mV
a
b
c
1
2
0
10
20
30
40
min

FIG 3

USE OF NUCLEAR TECHNOLOGY IN THE CONTROL OF INSECT PESTS

Dr. Rohini Hewamanna
Radioisotope Centre
University of Colombo

Over one million insect species inhabit the world. Majority of these insects are fortunately beneficial or harmless. The species that are detrimental cause losses estimated at between 8-20% of the total production of crops and livestock throughout the world. Very significant losses are caused by insects during storage of agricultural products. Losses also occur from human diseases such as malaria and dengue that are transmitted by insects.

For more than fifty years man has relied mainly on insecticides to kill insects that ravange crops. The impact of modern pesticides on agricultural production is such that the total withdrawal of these chemicals would reduce the output of crops and livestock considerably and increase the price of farm products. Because of the harmful effects of these chemicals efforts have been made to develop safer alternatives to pesticides. All these alternative methods are of limited applicability and need specialized management. Therefore the use of pesticides is expected to continue. However, more environmentally conscious alternative methods of insect control are required. One such alternative method is the use of isoptes and radiation in the control of insect pests.

Nuclear techniques are commonly used in studying the environmental fate of pesticides in different environmental matrices and the metabolism of pesticides in animals and plants. Radioisotopes are used as tags or markers of insecticides, insects or plants. With such tags one can follow the fate of insecticides within insects and the environment, the movement of insects under field conditions and the incorporation of nutrients into the insects. They can be used to follow parasites and predators of insects, to monitor their numbers, movement and ability to help control insect pests. Radioisotopes are also used to identify the degradation products of pesticides and in preparation of pesticide formulations.

The use of radioisotopes such as tritium, C^{-14} and P^{-32} as tracers in pesticide research are well established. A pesticide molecule labelled with a radioactive atom can be easily traced among scores of non labelled chemicals found in the environmental matrices by using radiation detectors. The degradation products can be separated from the other chemicals by conventional methods and quantified by estimating the radioactivity associated with them. The radio tracer technique is very reliable and very sensitive to detect minute quantities of a substance. As such nuclear techniques have played an important role in developing safer and more effective pesticide delivery systems.

In another approach to control insect pests radiation is used to sexually sterilize insects. The technique is known as the Sterile Insect Technique-SIT. H.J. Muller who was awarded the Nobel Prize for his work on the genetic effects of irradiation in insects demonstrated that X-rays or gamma radiation could cause genetic damage to insect reproductive systems to induce sterility. The SIT is an approach to insect birth control. The technique is highly selective ecologically in that it affects only the targeted species.

It exploits the mate seeking behaviour of the insect. Insects are reared in mass numbers and sexually sterilized using gamma rays from a Co-60 source. The sterile insects are thereafter released in a controlled manner into the required environment. When matings occur between the released sterile insects and the wild insects, offspring will not be produced. If sufficient matings occur the insect pest population declines. With continued release the insect pest population can be controlled and in some cases eradicated.

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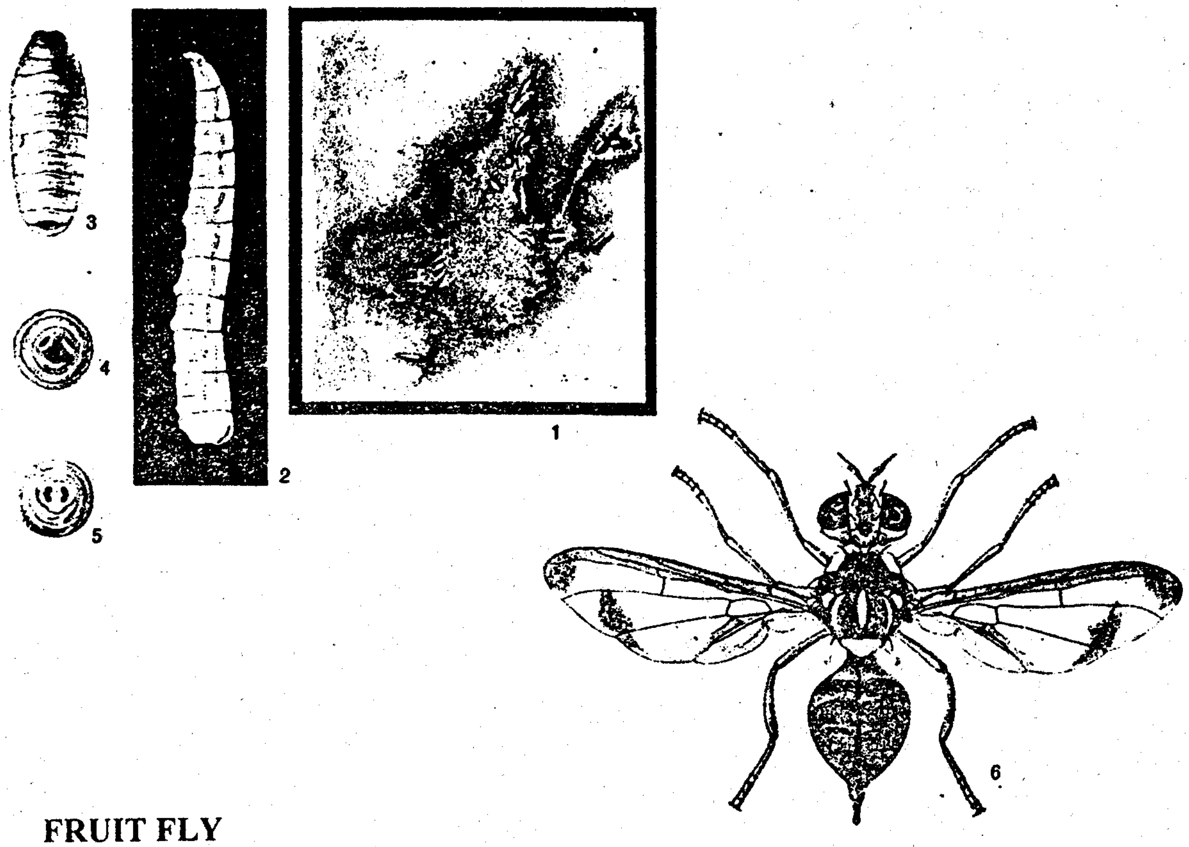
The first demonstration of this technology was the eradication of the screw worm from the islands of Curacao and Sanibel in the 1950s. This project was international. To a large extent operational SIT projects since then have remained international in scope. SIT has successfully been used against tsetse fly, Mediterranean fruit fly, pink boll worm and the melon fly.

Although the basic idea appears simple, the application of the SIT requires considerable biological sophistication. The basic idea of the technique theoretically suggests that it could be applied against any insect pest that reproduces by sexual means. However, in practice obstacles can be encountered. For some insects such as butterflies and moths the main difficulty is mass rearing. These insects belonging to the order Lepidoptera are amongst the major insect pests in the world. Another problem is that many moths are difficult to sterilize with radiation. They require a radiation dose 2-10 times greater than that for flies. These large doses have been observed to reduce the competitiveness of the released insects. During the recent past mass rearing of this insect group have been successful on artificial diets. Also a modification of the SIT called the F1 or inherited sterility method has been developed to suppress butterflies and moths. In the F1 method much lower doses of radiation are used so that the released males are only partially sterilized and the females are fully sterile. **Hence, when released females mate with native males no progenies are produced. When released males mate with native females a reduced number of progeny is produced but the offspring are completely sterile.**



FRUIT FLY

1. Maggots in fruit 2. A single larva 3-5. Pupa along with details of extremities 6.Adult

The SIT is effective for area wide insect eradication programmes. It is not applicable on an individual field or farm basis. SIT programmes tend to be large and are considered expensive. However, when applied against very damaging and widely dispersed insects the cost per unit area of land is less than the cost of each individual field being treated separately by other technologies. Other factors favouring the use of SIT includes the growing problem of insect population that become resistant to insecticides and concerns about the environmental damage caused by the continuous use of insecticides.

To conclude two special benefits should be stressed with regard to SIT. SIT can suppress and eradicate insect pests in an environmentally harmless manner. It combines nuclear techniques with genetic approaches and replaces intensive use of insecticides. In some SIT programmes insecticides are used sparingly at the outset to reduce the size of the insect pest population before sterilized insects are released. However, the amount of insecticides used in such programmes is a fraction of what would be used without SIT. SIT is suited for use in integrated pest management programmes to achieve control at the lowest possible price with a minimum contamination of the environment with chemicals.

INTEGRATED PEST MANAGEMENT PERTAINING TO THE G.C.E. (ADVANCED LEVEL) ZOOLOGY SYLLABUS

JAYANTHI P. EDIRISINGHE
Dept. of Zoology, Faculty of Science,
University of Peradeniya.

Integrated Pest Management (IPM) is one of the topics listed under Pest Management (Unit 10.3.3) in the current G.C.E. (A/Level) Zoology syllabus. The purpose of this article is to present the concept of IPM, and to lead a discussion on how it came into being and the principles underlying its application.

Integrated Pest Management is a concept that came into being following the problems that arose due to the total reliance on synthetic organic insecticides for pest control. Chemical control which was used extensively until recently made no consideration to the ecosystem, changing population levels of the pest insects and the health hazards. More over, the use of a single method of control was found to be inadequate to solve the complex pest problem. Hence, the idea to "integrate" different methods of pest control and to "manage" insect populations rather than to control them was proposed. The integrated approach to pest control is now accepted as the best strategy and it attempts to achieve a compromise between chemical control and other methods of pest control.

Integrated pest Management

Integrated Pest Management is defined as the utilization of all suitable techniques and methods, in a compatible manner to maintain the pest population at levels below those causing economic injury to the crop.

An IPM programme is implemented on a crop to manage the different pest species that cause economic injury to that crop. The implementation of an IPM programme on a crop has to be carried out in stages involving the following steps.

(1) Determine whether the insect species that causes damage to the crop has reached the pest status".

(2) Study the population dynamics (or population changes) of the pest species over a period of time in order to establish Economic Threshold and Economic Injury Levels, at which control methods are to be initiated.

(3) Determination of the possible effective methods of control of the pest.

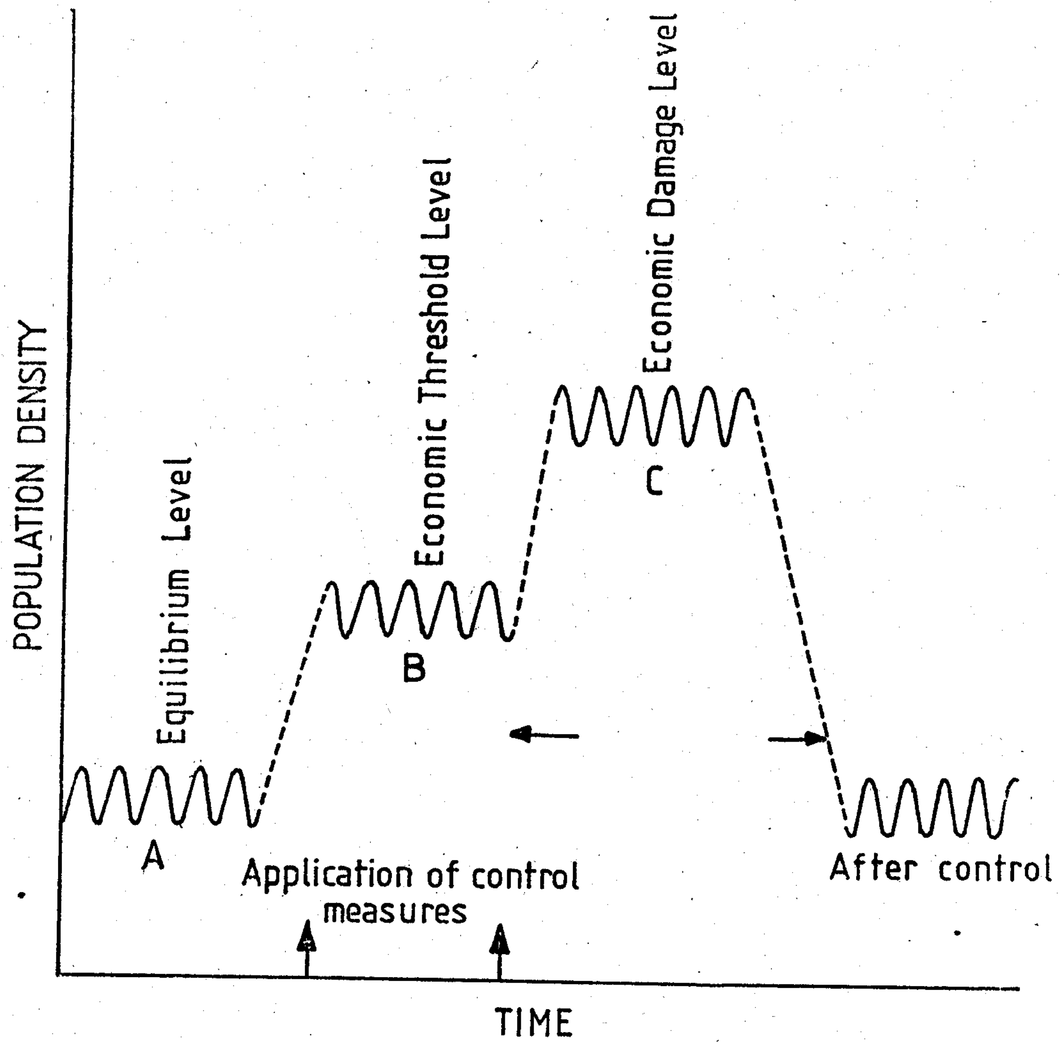


Fig.1 Fluctuations in an Insect population

Integrated Pest Management is defined as the utilization of all suitable techniques and methods, in a compatible manner to maintain the pest population at levels below those causing economic injury to the crop.

Thus the concept of IPM has to be discussed in terms of the pest status, population dynamics of the pest, pest management and methods available for pest control. I shall set out to define and explain each of these aspects within the frame of IPM.

Pest status

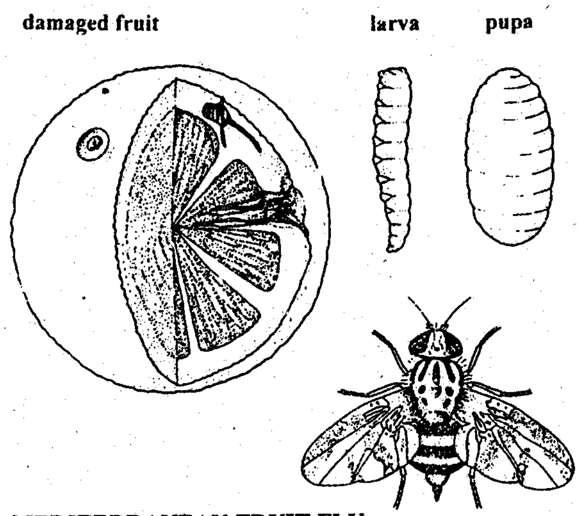
There are several definitions for the term pest. Most of these definitions emphasize two aspects of the pest, namely; their abundance on the crop and the degree of damage caused to the crop due to the activity of the pest. The abundance of a pest is described in terms of numbers of insects on the plant or the crop, while the degree of damage caused to the crop is described in economic terms.

The degree of damage or harm caused by insect pests to the crop is very variable and hence difficult to evaluate. It is dependent on several factors. Some of the important factors are;

(1) the species of insect concerned,
(3) the density of the pest insect population and
(3) the stage of growth of the crop,
(4) the economic value of the crop.

A few insects of a given species feeding on a specific crop may not cause sufficient damage to bring about an economic loss to the farmer. Hence, such an insect species would not be considered a pest. But when the insect numbers increase with time under certain conditions, the damage caused would lead to an economic loss and the insect species becomes a pest. Thus, the population level of a given insect species determines to a greater extent whether it is a pest or not.

Fig. 1 illustrates the changes in population level with time, that can be reached by an insect species on a given crop due to changing conditions. Line **A**, represents the population fluctuations achieved under non-pest conditions referred to as the General Equilibrium Level. A population is known to be at General Equilibrium due to external natural causes maintaining a balance in the insect population at a level that does not cause economic damage. Natural enemies such as parasitoids, predators, pathogens and weather conditions are some of the natural external factors that keep insect populations in check.



MEDITERRANEAN FRUIT FLY
(Ceratitis capitata)

However, due to several reasons such as changes in climatic conditions and man's activity, the population of a given insect species may continue to increase and go through a level represented by line **B**, referred to as the Economic Threshold Level. Below this level or at this level of population no economic damage to the crop would take place.

But if the population of the insect species continues to increase further, economic damage or a loss to the farmer is inevitable. This level of population is represented by line **C** and is referred to as the Economic Injury Level. At this level of population the insect species is said to have reached the pest status.

Pest Management

Methods to counter the increase in population of the insect species has to be brought in at the Economic Threshold Level, ie. well before their numbers increase to reach the economic injury level. Furthermore, the methods selected for this purpose should be applied in such away that the insect population is brought below the Economic Threshold Level to reach the Equilibrium Level and not to zero population level. This is the essence of pest management, where one does not attempt to completely eliminate the entire pest insect species from the crop. When the pest population is brought down to the Equilibrium Level, through pest management practices, it is expected that the natural forces would keep the population in balance.

One might wonder how one decides or finds out whether an insect species on a crop has reached the economic injury level and hence become a pest. The different population levels shown in Figure 1. are determined through experimentation by a long term study of the insect population on the crop. Furthermore, several factors such as

(1) the nature and economic value of the crop,
(2) field conditions and
(3) the type and degree of damage to the crop are considered in the determination of the Economic Threshold Level of a specific insect pest on a crop.

As an example of Economic Injury Level, I like to quote the case of the Brown Plant hopper (BPH) of paddy, namely, ***Nilaparvata lugens***. The Economic Injury Level of BPH has been determined as 5-8 hoppers per hill at the tillering stage of the paddy plant and 10 hoppers per hill at the nature stage of the plant. What this means in practical terms is that, when the number of hoppers reaches an average of 5-8 or 10 per tiller (depending on the stage of growth of the paddy plant) economic damage results in causing economic losses to the farmer. Hence, it is necessary to ensure that the hopper numbers are kept below these levels using suitable pest management methods.

Pest control through the ages

From the earliest times, farmers were engaged in the use of several, time-tested agricultural practices to reduce damage by insects. We now refer to these methods as cultural methods of control. Together with unhampered natural insect control methods that existed then, insects were not a problem to farmers. natural enemies of pest insects such as predators, parasitoids & pathogens and environmental factors that are not conducive to the build up of insect populations, acted as natural control methods.

With the advent of time and increase in human population, the demand for food production increased. This necessitated the growing of high yielding crop varieties and the use of chemicals against insects, to reduce pre-harvest and post harvest food losses. The chemicals that were used initially included inorganic compounds such coper and lead. With the need for stronger and quick acting chemicals, synthetic organic chemicals came into usage. These included initially the organochlorides, followed by organophosphates, carbonates & pyrethroid insecticides.

However, the use of chemical methods of pest control resulted in several adverse effects in the long term, such as

(1) the development of resistance to insecticides
(2) creating new pests out of non pest species,
(3) rapid resurgence of pests,
(4) affect on non target organisms including man and
(5) environmental pollution.

Thus, the use of extensive and wide scale use of chemical pesticides instead of solving the pest problem has created new and difficult problems. It soon became clear that chemical pesticides alone cannot solve most pest problems. There was, therefore an urgent need to re-examine traditional cultural methods for pest control and to make greater use of naturally occurring control methods. In addition, new methods which are ecologically sound, long lasting and causing very little or no disturbance to man, other animals and the environment had to be examined.

The need to combine limited and specific use of chemical pesticides with other methods of pest control led to the development of the concept of Integrated Pest Management. The application of IPM involves the manipulation of the insect population by means of a variety of control methods in order to reduce their damage below economic injury level.

For the application of IPM it is necessary to obtain basic information about the pest species such as its abundance and distribution, biology and behaviour, natural enemies and effective control methods. This knowledge about the pest would help in determining the

(1) vulnerable stage of the pest
(2) suitable time to initiate control measures
(3) most effective method of control

The major insect pest control methods that can be used in an integrated pest management programme can be broadly stated as cultural, chemical and biological methods. Of these methods, except chemical control, the other methods can be used together in a compatible manner. Although, chemical methods of control, act counter to biological methods, it is desirable to minimize the use of insecticides and avoid their misuse, rather than to ban them altogether. For this purpose, pesticides that are specific in action (that act only against target insects) and are less hazardous to animals and man are to be used in Integrated Pest Management Programmes. Furthermore, by the limited use of such insecticides, the numbers of insects on crop can be brought down to a manageable level at which biological control (and cultural control) can take over and act effectively.

As mentioned before, the main methods used in IPM are cultural, chemical and biological. These three methods are also included in the G.C.E. A-Level syllabus as methods of pest control to be discussed. Hence, I would very briefly state the principles underlying these methods of control.

The major insect pest control methods that can be used in an integrated pest management programme can be broadly stated as cultural, chemical and biological methods. Of these methods, except chemical control, the other methods can be used together in a compatible manner.

Cultural Control Methods

Methods that come under cultural control are mostly the traditional agricultural practices that have been carried out by farmers for generations. Some of the methods used in paddy cultivation are

(1) crop rotation
(2) crop sanitation
(3) growing of trap crops
(4) ploughing,
(5) water management and
(6) growing of resistant crop varieties

Chemical Control Methods

Use of chemicals that have insecticidal properties are used in this method of control. Insecticides are commercially available in the form of sprays, granules and dusts. The synthetic insecticides that are commonly use belong to 4 broad groups.

(1) Organochlorids such as BHC and Aldrin
(2) Organophosphates such as Malathion, Parathion
(3) Carbonates such as Carbofuran, Carbaryl
(4) Pyrethroid such as Permithrin, Pyrethrin

Biological Control Methods

The use of natural enemies of insects in the control of insect pests is termed biological control. Natural enemies of insects belong to three groups.

(1) Predators: insects that feed on other insects including the eggs, larvae, pupae or adults of prey insect.

(2) Parasitoids: insects that lay their eggs on other insects either on the egg, larval of pupal stages of the host insect.

(3) Pathogens: organisms that cause diseases in insects. These include the viruses, bacteria, fungi, nematodes, and protozoans.

Recently, under biological control methods are included methods that rely on (a) insect pheromones (that act in very small concentrations and hence called semio chemicals), (b) release of genetically altered insects into the population such as the Sterile Male Release Technique.

Integrated Pest Management is accepted as an ecologically safe method of reducing the number of insect pests on food & other crops. it involves the integration of cultural, chemical and biological methods of pest control. Through the use of IPM the population of pest insects are brought down to a level that is no longer economically harmful to the farmer. IPM which is now a universally accepted form of pest control in a given crop is widely used in the developed countries. It is being applied for the control certain rice pests in Sri Lanka.

'Farmer Field Schools' A New Approach on IPM Training

M.H.J.P. Fernando
Director
Seed Certification & Plant Protection
Department of Agriculture
Peradeniya

Integrated Pest Management (IPM) is concerned with combining a number of techniques in a particular cropping system for a whole range of pest species in order to provide an overall coherent strategy for pest management. IPM is now considered as a pre-requisite to the development of sustainable agriculture and ultimate aim of IPM is to redress the lost ecological balance in agro-ecosystems invoked by the adoption of unilateral pest control strategies.

Sri Lanka has been implementing an IPM program for rice with the assistance of FAO-Inter Country Program since 1984. At the beginning of the project, main emphasis was to provide training to all the extension officers in order to commence field demonstration and farmer training. During this period almost all the agricultural extension officers in the country totalling to more than 2500, and over 10,200 rice farmers have been trained on IPM practices. The extension officers were trained as trainers. They trained the farmers. The success shown by pilot scale IPM demonstrations initiated at early phases of the project in few districts provided the impetus to expand the program to 24 agricultural districts including North and East and five major irrigation project areas (Mahaweli) during the two phases of the project. Today IPM has received a national recognition after being declared it as a policy recommendation in the national food production program in Sri Lanka in 1995.

Successful implementation and sustainable adoption of IPM has been largely due to the novel training methods and effective training/demonstration programs conducted for not only trainers but the farmers as well. At initial stage of the project. IPM training provided was only short-term and the duration did not exceed maximum of two weeks. Most of the training was limited to class-room based conventional methods where information were given primarily in the form of pre-determined advises through flip charts and teaching aids: only little field activities were included. Thus flow of information followed a one way process-only from extension worker to farmer.

Because of the less confidence and skills of farmers on IPM and decision making has not developed to the expected level. For successful adoption of IPM, the farmer must (a) be able to identify problems (b) have access to appropriate control measures and © have the confidence to make appropriate choices or decisions on crop management.

Despite the considerable efforts made at initial stages of the project. IPM gained less prominence among the farming community and this has been largely attributed to the inherent drawbacks in the training process. However, continuous evaluation of the training methods and training requirements have paved the way to make appropriate adjustments and improvements to make the training more effective. Experience of other countries was also shared in improving the training methodology. As a result, the training has transformed into more practically oriented, season-long field level program where farmers are exposed to develop practical skills and decision making on IPM through their own observations in the field. Through this improved training methodology which follows 'learning by doing' approach, farmers acquire a complete knowledge on cultural practices, biology of rice plant, the relationship of pests and natural enemies and other aspects of the rice ecosystem ecology. All learning activities are based on the direct field observations carried out once a week for a whole growing season and the system of training is known as Farmer Field Schools.

Training Approach in Farmer Field School

Whole training curriculum is experimental and discovery based, aimed at the enhancement of technical IPM expertise, knowledge as well as practical and diagnostic skills among farmers. The curriculum is no limited to pest management pe se, but encompass other related areas such as agronomy, biology, ecology, economics etc. to form a holistic approach. No formal lectures are delivered. Instead, training activities are designed to have trainees learn by doing. More than 50% of the training time is spent in the field as it being the main source of learning. The educational program does not provide packages that present weekly messages. Instead, the program take a broad integrated approach to working with farmers based on the principles that farmers need to learn during a whole seasonal cycle- from planting to harvesting. Farmers generate their own learning materials from field observations and action research. Exchange of information and knowledge is facilitated through observation, brainstorming and discussion within and among farmer groups during the training sessions. Trainers are primarily acting as facilitators and only inject knowledge and information when felt necessary.

This approach also facilitates participatory action research which aims to provide trainers and farmers with analytical ability and skills to investigate into cause and effect relationships of local farming problems. Within IPM training, 'problems' are seen as challenges, not constraints. These challenges stimulate farmers to design a set of action for solving field'problems' such as varietal trials, fertilizer trials, natural enemy exclusion and defoliation trials etc. Field extension workers and farmers are equal partners in the whole process.

What is "farmer Field School"

IPM Farmer field school is a group of about 25 farmers who have agreed to meet at weekly intervals in the field to learn on integrated crop and pest management through filed observations, for an entire cropping season - starting from land preparation through planting to harvesting. Each weekly meeting will run for about half a day and usually 12 to 16 such meetings will be included for the whole training program. This program is also called "a school without walls" as the entire field is being used as a class room for the training.

In each weekly meeting, the farmer group may break into five sub-groups or small teams of similar number and spend one to two hours in the field that contains a farmer - run comparative study of IPM.

The members of the group make their own field observations on various aspects of crop growth including plant health, water management, nutrient status, weed growth. They also collect information on insect pests, predators and parasitoids. The damage caused by pests and diseases are assessed.

Each team then assembles outside the field, discusses the observations made, recognizes pest and non-pest species, analyses the data collected and attempts to provide a causal interpretation about the crop growth status in relation to abiotic and biotic components in the field. The whole exercise is known as Agro Ecosystem Analysis. Usually, the results of the analysis are summarized in a diagram, called ecosystem diagram, and each team presents their diagram to all members of the Field School. Each diagram include a drawing of a typical rice plant in its growth stage for that week. On one side of the rice plant insects/organisms that are supposed to damage rice plant are drawn with giving their population size while on the other side, insects/organisms that feed on the pest organisms are drawn. Information on other ecological factors are also summarized in the diagram. This validates, from field observations, the concept of the balance in nature and of population regulation in a representation that is created by farmers. The experience and knowledge gained through field exposure coupled with the induction received from intra and inter group discussions help the farmers to determine weather pest control is necessary at a given period of crop growth. The ability and confidence of making appropriate decisions on pest management is further enhanced through the direct field experience gained from participatory research activities set up to demonstrate fertilizer requirements and alternatives, the effect of crop damage on yield and plant compensation for damage as well as impact of pests and effectiveness of alternative control techniques.

Recent Developments in IPM Training with FFS

Forty three officers engaged in agricultural extension and education obtained season long training for conducting FFS and graduated as IPM specialists in 94/95 Maha. They started IPM activities from the following Yala season with the latest techniques learnt through the season long training. During this period, these specialist trainers in the DOA conducted FFS each district covering almost the entire country except three districts.

In accordance with the government policy, it was necessary to expand IPM program to cover as many rice farmers as possible. Hence the specialist trainers supported the district program also by training extension officers at their FFS sites through-out the season. Altogether 94 field officers trained in this manner. In addition, the IPM specialist trainers attached to training institutes also trained 84 extension officers to further strengthen the IPM/FFS program. All these trained officers have initiated FFS in their respective districts during 1995/96 Maha season with the assistance of IPM specialist trainers. From 1995 Yala through 1995/96 Maha, around 2200 farmers across the country have undergone IPM training through FFS at the hands of specialist trainers. These farmers are motivated to guide other farmers when faced up with management problems and also act as catalysts in spreading the IPM message.

In order to expedite the expansion of IPM through FFS and further strengthen the training capacity and capabilities of district extension service, the second season long training program was started in November 1996. A group of 36 field officers selected from different districts and Mahaweli Economic Agency have successfully completed this course in February 1977, with them, the number of specialist IPM trainers in each district have increased from one to two.

Major part of the second season-long training has been conducted by the staff of Plant Protection Service who underwent a similar training at the hands of expert resource persons provided by the Inter-Country Program for rice IPM. After conducting of the second season-long training, the trainers from Plant Protection Service have got an adequate experience in conducting and management of season-long training all by themselves. Hence now DOA is equipped with a cadre of national level master trainers who are competent enough to conduct long term training on IPM through FFS.

Impact of IPM Training

The IPM is gaining an increasing popularity among local farming community since the adoption of the experimental learning approach through FFS. The trained farmers are more knowledgeable about both environment and agriculture. Their pesticide use has changed. They have begun to take more rational approach to use pesticides. Pesticide use is guided by necessity, when and how much depends on observations and analyses of field condition. Results of FFS conducted all over the country during Yala 1995 season revealed that frequency of pesticide application has reduced by more than half, thereby reducing the cost of pesticides by 50-70% while increasing yield by 9-25%. Results of FFS conducted in 1995/96 Maha further support and confirm these observations.

Results of IPM are more impressive when data of the same season between IPM and Farmer Practice (FP) plots are compared. Average frequency of pesticide application has been further reduced., almost by 90 percent where by reducing the cost of pesticide by 90 percent. Yields have been consistently higher in IPM plots than in FP plots.

Follow up studies revealed that there had been also a lateral spread of information on IPM technology among neighbouring farmers leading into reduction of unnecessary pesticide application that they were used to practice previously.

Total extent of 200 hectares with 431 farmers were covered under IPM-FFS program during Yala 1995 season. The total savings on pesticides accrued these farmers due to IPM during Yala 1995 season was approximately Rs. 541393/=. The learning process of the field school also increased the skills and capabilities of farmers. They were more rational when presenting their views and ideas. They have also become skilled in carrying out trials, either at their homes or in the field. Farmers were able to identify major rice pests and their defenders. Their diagnostic capabilities on field problems were improved.

Among the positive impacts of the Farmer Field School approach has been the development of the attitude of the farmers. They felt proud because they have become educated. Therefore their participation has been very enthusiastic.

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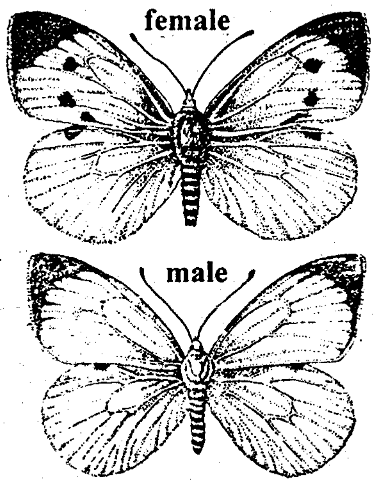
Expansion of IPM

The Hon. President in her policy statement clearly outlines the Governments's interest in popularizing IPM. Presently IPM/FFS program is applied only to rice.

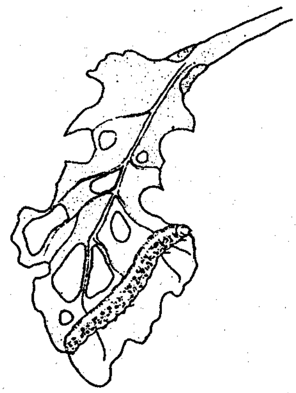
But there is a keen interest and a demand for IPM in other crops, especially vegetables because the highest levels of pesticide overuse is happening in vegetable growing areas.Preliminary studies conducted recently on IPM/FFS for chilies and some vegetables showed encouraging results.

The staff for IPM implementation comes mainly from the Provincial Extension Service. There is a need to upgrade the training capabilities of these officers which will be done gradually.

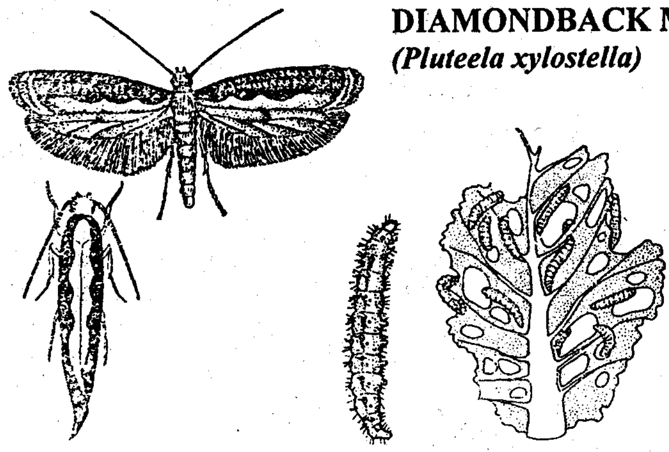
LEAF EATING CATERPILLARS



LARGE CABBAGE WORM
(Pieris brassicae)



DIAMONDBACK MOTH
(Pluteela xylostella)



Integrated Pest Management of food crops

C. Kudagamage,
Deputy Director (Research)
Horticultural Crop Research & Development Institute, Gannoruwa

Several hundred species of insects are known to damage agricultural crops and inflict severe losses in food production. Different pests feed on all parts of the plants, transmit diseases and damage the produce in storage.

Insects account for an average of 10 - 15% yield losses. There is no accurate information on yield losses caused by insect pests and available data are based only on few random studies carried out in specific location by various workers (Table 1).

Table 1: Crop losses by insects

Crop	Pest	Extent of damage	Reference
Cabbage	Cabbage caterpillars	12-13%	Jesudasan and Yogaratnam,1985
Brinjal	Brinjal pod borer	50%	Mylvaganam, 1983
Beans	Beanfly	40-50%	Anon., 1990
Legumes	Beanfly	15-30%	Subasinghe and Amarasena,1983
Soya bean	Pod borer	05%	-
Black gram	Pod borer	18%	Anon., 1984
Cowpea	Pod borer	23%	-
Rice	Brown planthopper	3.1%	Kudagamage and Nugaliyadda 1990

Need for alternative method

There is a need for control measures to be adopted to prevent damage caused by insect pests. Most often insecticides are used as a first line of defence against insects. Today many who continued to practice chemical farming relying solely or heavily on pesticide inputs are confronted with many problems and an increasing threat of non-sustainability.

Disruption of Natural Enemy complex: Pest species are kept below damage threshold by the action of natural enemies comprising parasites, predators and other pathogenic organism. Insecticides can disrupt natural enemy complexes and result in pest out breaks.

Change in pest species: Prior to the 1970s, one of the major pests of rice, rice brown plant hopper (Bph) was a minor pest. However, use of broad spectrum insecticides for the control of stemborers, then one of the important pest, resulted in the destruction of natural enemies of Bph and as a result Bph became a major pest of rice. Generally speaking insecticide treatments brought about an imbalance in the agro-ecosystem, that is a decrease in total number of species but with an unexpected increase in the population density of few pest species.

Insecticide Resistance: . Continuous use of insecticides result in the development of insecticide resistance. When insecticides are used majority of insect populations die leaving behind few individuals capable of withstanding the insecticide due to its genetic nature. These few individuals breed and produce the next generation of individuals exhibiting more resistance than the previous generation. This process continues and within few generation most of the individuals in the population are resistant to insecticides. The tomato leaf minor, ***Lariomyza trefoil*** is virtually resistant to all available insecticides.

Hazards: An approach of pest management solely dependent on insecticides will have many drawbacks. For instance farmer may use a wrong concentrations. When a lower dosage is used, the insecticide may not be effective. If a higher concentrations used it will increase the cost. Additionally there are some application problems such as insecticidal drift and health hazard to applicators. Insecticidal drift result in contamination of water ways, range lands and parks. Insecticides like organochlorines accumulate in the food chain killing wild life like birds. Residues that remain on harvested products can result in various health hazards. Contaminated products may be rejected by the exporting countries. For example, in Germany, Tea will not be accepted if they detect pesticide residues in processed tea.

INTEGRATED PEST MANAGEMENT APPROACH

Integrated Pest Management (IPM) is a broad ecological approach to pest management utilizing variety of control strategies compatibly in a single pest management system.

In IPM stress is placed on the importance of realistic economic injury levels which are used to determine the need for control actions. At the sametime everything possible is done to protect and preserve naturally occurring biotic mortality factors such as parasites, predators and pathogens. When artificial control measures are needed for example chemical pesticide application, they are employed in a selective manner as possible and only when their use is economically and ecologically justified. The ultimate objective of the IPM is to produce optimum crop yield of high quality at minimum cost, taking into consideration the ecological and sociological constraints in that particular agro-ecosystem and the long term preservation of the environment.

Complete freedom from insect attack is neither necessary in most cases for high yields nor appropriate for insect pest management. Nearly all plants can tolerate a substantial degree of leaf destruction without appreciable effects on plant vigour. Hence estimate of the pest density should be available which delineate the pest population level below which damage is tolerable and above which specific interventions are needed to prevent a pest outbreak and to avert significant crop injury.

This quantitative insect density is given by the economic injury level. This is defined as the critical population density where the loss caused by the pest equals in value of the available control measure. Economic threshold is another important parameter defined as the density of the pest population at which control measures should be applied to prevent an increasing pest population from reaching economic injury level. The economic threshold always represents a pest density lower than that of economic injury level, to allow the initiation of control measures so that they can take effect before the pest density exceeds the economic injury level.

The pest population fluates above and below the general equilibrum position. This is the average population density over a long period of time as affected by the temporary intervention of pest control. The economic injury level may be at any level from well below to well above the general equilibrium position. Insects can be grouped into four general categories in this regard (Figure I).

1. Many insect pest species feed on cultivated crops without ever reaching densities high enough to cause economic injury. Examples include grasshoppers and aphids feeding on rice (Figure I A).

2. Another large group of insects are occasional pests and exceed economic injury levels only when their populations are affected unusually by weather conditions or injudicious use of insecticides. Examples include rice ear cutting caterpillar, ***Mythimna, seperata*** and white back-plant hopper ***Sogatella furcipera*** (Figure 1 B).

3. A third group of insects has economic injury level only shortly above the general equilibrium position and intervention is necessary at nearly every upward population fluctuation. Examples include rice brown plant hopper, ***Nilaparvata lugens*** and pod borers of legumes (Figure 1 C).

4. Severe pests are found in a group of insects having economic injury levels below general equilibrium position. Examples include various fruit fly species - infesting various fruits and mosquitoes which act as vectors of human diseases. Regular and constant interventions usually with insecticides are required to produce marketable crops (Figure 1D).

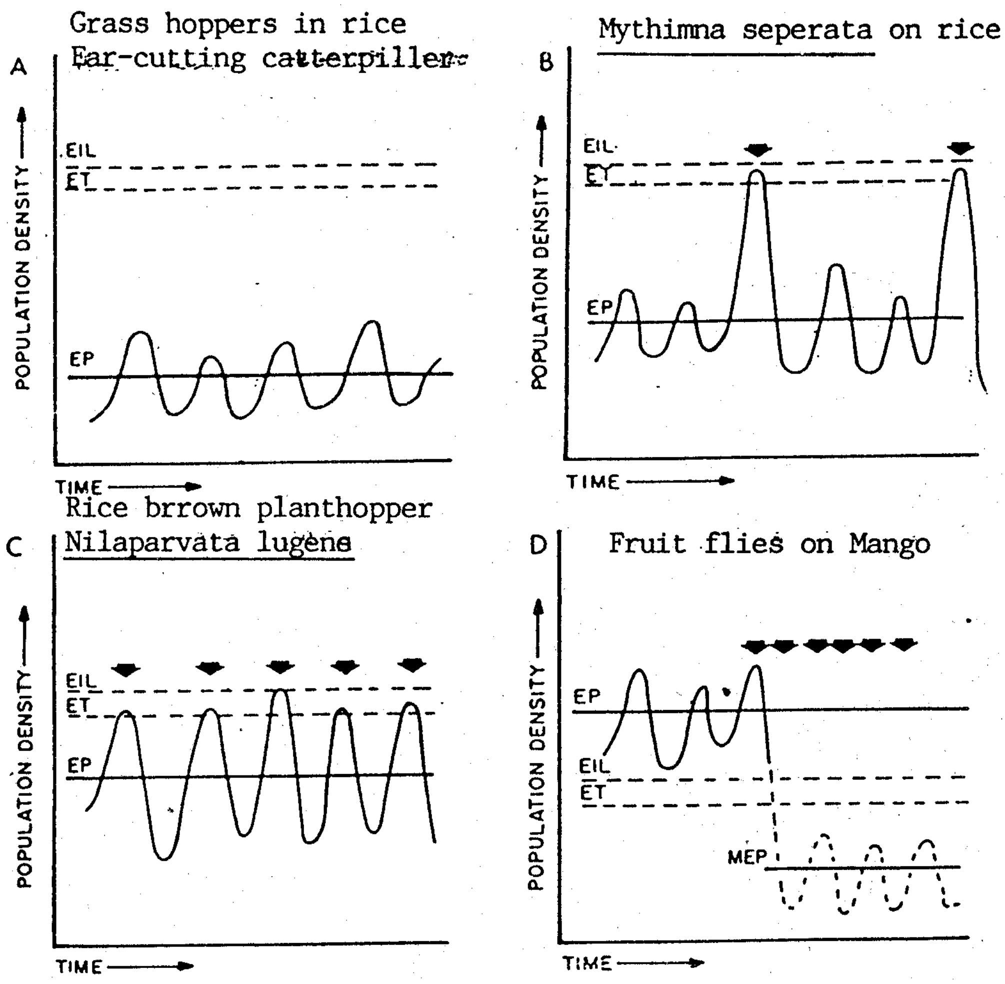


Fig. 1. Economic injury levels and economic thresholds for typical insect pest situations. EIL, economic injury level; ET, economic threshold; EP, equilibrium position; MEP, modified equilibrium position; arrowheads, pest-control intervention. (Modified after Stern 1965.)

REQUIREMENT OF PEST MANAGEMENT DECISIONS:

1. A pest management should be able to identify the different pests that infest the crop at different stages. He should be able to categorize different insects infesting different crops as explained in the above section so that pest status of the insect can be evaluated.

2. The actions, reactions and intera ctions of components of agro-ecosystems that affect significantly the target pest species should be known. IPM emphasises existing factors in the ecosystem which check the pest's numerical growth: Limited resources (food, space, shelter), periodically inclement weather or other hazards (heat, cold wind, drought, rain) competition within the species or with other plants and animals and natural enemies.

3. Pest populations are dynamic, some times, more than doubling in a day or decreasing at comparable rate. Because of weather, crop growth, natural enemies and other factors that affect population growth and decline, pest population and parts of the environment influencing their abundance must be monitored frequently in order to determine when to apply or relax various control measures. Only through monitoring can the real need for control be known and the natural control maximized.

4. An assessment of potential ecological or environmental hazards that may occur with control measures.

COMPONENTS OF IPM

There are several methods of insect control. The methods currently available and proved effective are cultural, biological, host plant resistance and chemical control. The combining of several of these into a comprehensive IPM programme can provide better suppression of key pest species and at the same time place less demand on any one method.

Cultural Control

Cultural control is the use of cultural practices associated with crop production to make the environment less favourable for survival, growth or reproduction of the pest species.

Cultivation of Soil: Many insects live or hibernate in the soil, selecting suitable temperature and humidity conditions. These conditions can be disturbed by ploughing which creates temporary drought conditions in the upper layer of soil and may even expose larvae and pupae to the radiation of the sun and promote activity of predators.

Clean Cultivation: Standard farm hygiene is important for pest control. The destruction of crop removes residual pests such as the stemborer pupae. The elimination of weeds deprives the pest of it's alternate hosts.

Manuring: Rapid healthy plant growth generally compensates for some damage by pests while weak deprived plants may easily be killed by an equivalent attack.

However, excessive use of nitrogen fertilizer should be avoided and a balanced fertilizer mixture containing potassium and phosphorous should be used. Application of organic manure reduces infestation in crops.

Irrigation: Many workers describe pest control effects of excessive irrigation or watering. Pests may be washed off the plants, drowned or suffocated. Soil insects may be killed by the pressure of colloidal particles in saturated soil. Partial control of rice thrips is possible by the temporary submergence of the crop. A reduction in the population of brown hopper is made possible by draining the fields when the crop is infested with brown plant hoppers.

Crop Rotation: The objective of the crop rotation is to isolate the pest from its host plant. Rotation is most effective against soil pests (e.g. wireworm and white grubs) which take a long time for maturity. It is also effective against pests like nematodes with low migratory capacity like nematodes.

Planting - harvesting dates: Variation of sowing date can control pests. Most of the pests exhibit seasonal frequency. Thus, either by the crop avoiding the egg laying period of the time pests appear, pest infestation is evaded. Timely cultivation can avoid infestation by thrips. Early harvesting removes pests from the field before they can emerge and perpetuate the population.

Varietal Resistance

The growing of crop varieties which are less attacked than others or yield well in spite of attack is a very good pest control measure. Once such varieties are available, the control requires no extra labour or materials and is therefore economical. Moreover, the environment is not affected from side effects of the control measure.

Insect resistance is most likely to be used as an adjunct to other control measures. Resistant varieties will need fewer treatments of pesticides. The presence of a low level of pests on a resistant variety enable the predators and parasites to maintain the pests below economic thresholds. Therefore, resistant varieties can be used along with bio-control.

One of the drawbacks of resistant varieties is the formation of biotypes. When genetically uniform crops are cultivated over a large geographical area, a few individuals that survive on these resistant varieties can multiply and produce a virulent biotype that is capable of surviving on previously resistant varieties. Such cases of biotype development has occurred on resistant gallmidge varieties in rice.

Biological Control

Biological control of insect pests reduces pest numbers by predators, parasites or pathogens. There are two aspects of bio-control important for an integrated pest management program. The first avoids insect control practices which disturb the biological control resulting from naturally occurring predators, parasites and pathogens already in the field. The second involves human efforts to enhance biological control, either through the introduction of natural enemies or through direct efforts to improve the efficiency of those already present.

At present, producing large numbers of predators or parasites in the laboratory for field release to control economic infestations of pest insects, appear to be less promising than conservation of natural beneficial insects in the field. Beneficial insects must have food, shelter and protection from detrimental effects of chemicals, dust and so on, over which man has some control. These requirements can be fulfilled in most agro-ecosystems by careful attention to crop planting patterns, rotation, harvesting practices and the use of sound economic levels on which to base insecticide application decisions.

Chemical Control

The development of an effective, economical pesticide, has profoundly influenced man's continual battle with insects. In many cases, chemicals have served as tools in insect control programs without serious hazard to humans or to the environment. However, there has been a tendency to regard these tools as a cure-all and to believe that for every insect problem there is a chemical which will magically control it. This has resulted at times in unwise, uneconomical or hazardous applications of chemicals.

It should be the responsibility of every user to learn as much as possible about the insect to be controlled, the chemical to be used and the potential hazards involved and then apply pesticides to minimize or avoid hazards and ensure effective, economical control.

Experience with Rice IPM Programme

The inter-country rice IPM Programme was launched under the auspices of the food and agriculture organization (FAO) in 1984. The programme comprised training, preparation of communication and extension aids and evaluation.

Training: To begin the programme, a number of counterpart officers from research, extension and eduction and training division of the Department of Agriculture (DOA) was sent overseas for training on IPM. The senior staff of the DOA were first familiarized with the goals of the programme through 4-day IPM workshop. As a second step, a specially designed 2 week "training-the-trainer" course for the implementation of rice IPM at the village level was conducted for middle level field officers.

These officers are expected to train the village level workers on IPM methodology. Recently, season long training programme was held for trainers at Angunakolapelessa. These officers who graduated as IPM specialist trainers subsequently started IPM training activities with the latest techniques learnt through the season long training.

Training of farmers are based on farmer field school approach. The IPM farmer field school (FFS) brings farmers together to undergo intensive training on IPM methods and issues over the life-cycle of the crop.

The field school trains the farmers to become IPM experts in their own fields. Training is focused on the analysis of the agro-ecosystem of the crop. This analysis helps farmers gain insight into ecological interaction in the field. The combination of analytical methods, ecological insight and basic IPM principles such as growing a healthy crop provides farmers with a wider base for confidence in their decision making.

Each field school comprises about 25 farmers. Such field school has its own field of 1000 m^2. The learning field is divided into two sections. The first is treated according to the mandated intensification package recommendation and the second is treated following IPM principles. These 2 larger plots serve as the basis for agro-ecosystem studies that are carried out by field school participants. Extension worker and a IPM trainer facilitate the activities of each field school.

Once a week farmers meet in the field around 8.00 a.m. The twenty five farmers divide themselves into five groups and field monitoring carried out in selected locations of the fields. During this; status of the crop growth, pest species found on the crop together with their numbers and number of different predatory species are recorded. After field monitoring a group discussion is held as to the status of the pest infestation and action needed. This procedure is repeated one day a week for 12 weeks covering the entire growing season.

Preparation of communication aids: Following publications have been obtained and distributed to extension staff.

* Posters on natural enemies of insect pests of rice (Sinhala, Tamil and English)
* IRRI-field problems of Tropical rice (Sinhala)
* Friendly insects (English and Sinhala)
* Rice IPM manual for extension workers (Sinhala & Tamil)

Slide sets on rice pests have also been used for training purposes. Subject matter specialist (SMS) and subject matter officers (SM) were given training on pretesting of extension communication aids through several workshops.

Evaluation: **IPM** trainers when selecting a demonstration tract carry out a baseline survey at the beginning of the season to determine pre-training rice production practices, expenses and profits with special emphasis on pest control practices of 25 farmer trainees.

Parallel comparative data are collected for the training season, when IPM area farmed by the trainees constitute a large demonstration.

A test on rice IPM knowledge and skill is given to farmer trainees before IPM classes begin to determine level of their knowledge and guide extension agents in designing appropriate class seasons. Identical tests are given at season's end to determine how much the farmers have learnt.

The results of these evaluations all over of the country provide ample evidence that the cost of pest control can be significantly reduced through IPM. Moreover yields have also increased due to good management levels in IPM fields thus increasing the profit margin of IPM farmers.