GREEN REVOLUTION AND INTEGRATED PEST MANAGEMENT

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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.

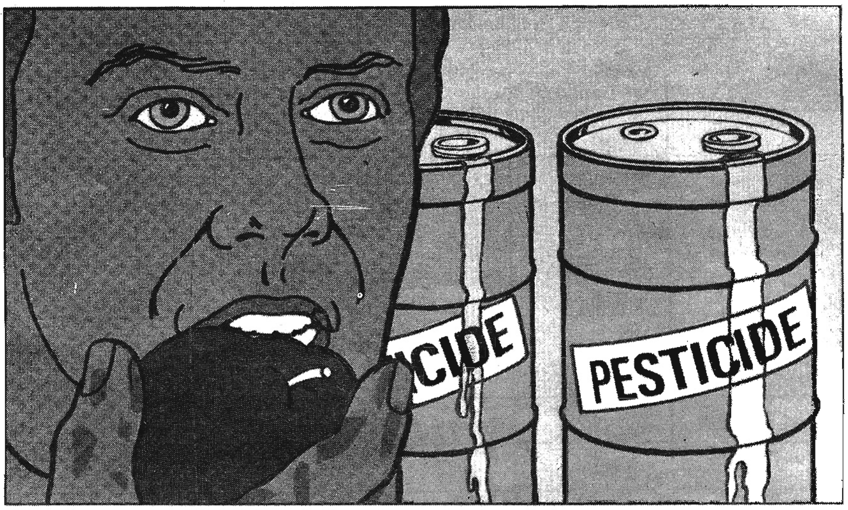
Although unwanted pests harmful to the crop can be destroyed by using pesticides, these compound can also cause another unforeseen problems. Let's judge a fascinating example showing consequences caused by using DDT$(C_6H_4CL)_2$:CH.C.CL_3-dichlorodiphenyl trichloroethane), one of the most effective 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

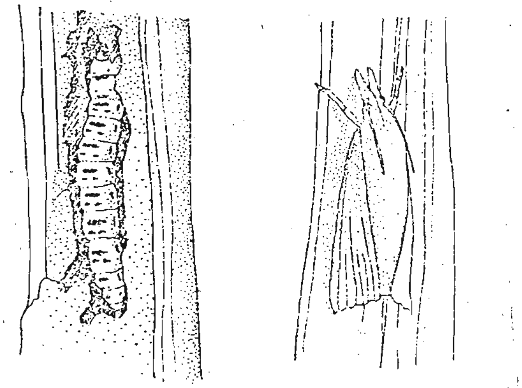
e. fertilizer applications

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.