ENT-601 Integrated Pest Management 3(2-1)

THEORY Introduction; history and concept of Integrated Pest Management (IPM); economics of pest management, population sampling, fluctuation and its measurement; different methods of insect pest scouting and forecasting; losses caused by insect pests to different crops; methods of pest management: cultural, physical, mechanical, legislative, chemical, biological, microbial, biotechnological and genetical measures along with antimetabolites, feeding deterrents, hormones and pheromones.

PRACTICALS Demonstration of cultural practices and different methods of pest scouting and monitoring, nature and extent of damage; assessment of crop losses by different methods; determination of economic threshold levels of 23 different crop pests; identification of important bio-control agents; installation of light and pheromone traps; familiarity with radiation techniques.

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CHAPTER-9

INTEGRATED PEST MANAGEMENT

Integrated pest management (IPM)is based on ecological principles and involves the integration and synthesis of different components/control tactics into a pest management system. Many components of IPM were developed in late 19th and 20th century. By early 1920s, a highly complex and sophisticated system involving the use of multiple component suppression techniques, viz. resistant varieties, sanitation practices and chemical treatments with calcium arsenate at fixed population levels, was clearly developed for the control of boll weevil on cotton in USA. However, during the period from 1920s to 1940s, the emphasis in crop protection shifted from cultural and biological control techniques to inorganic chemical pesticides.

The discovery of insecticidal properties of DDT rapidly followed by the manufacture of other broad spectrum synthetic organic pesticides during 1940s and 1950s virtually eclipsed all other techniques. These insecticides were easy to apply and produced an almost immediate kill. Therefore, they became our first and only line of defence or attack against all insects. However, even at that time, many scientists had warned regarding the consequences of exclusive reliance on chemical insecticides ignoring ecological principles. Unfortunately, their sane voices were drowned in the euphoria generated by the initial success of synthetic insecticides.

Since the middle of this century, the use of insecticides for the control of specific pests on crops or the use of fungicides against diseases has increased phenomenally. Their use was considered a necessity for increasing agricultural production at a reasonable cost. It was not realized at first how polluted the environment would become and how these chemicals or their ingredients would become accumulated in top soils. This realization came only when the recurrence of pests with even a greater severity was evidenced, as a result of the death of natural enemies alongwith the pests. The accumulation of chemicals in the soils also reduced crop productivity.

In the last two decades, an altogther new approach to the control of pests and diseases has been developed. The rationale behind this new approach was that all the experts interested in crop growth, i.e. the entomologists, plant pathologists, weed specialists, systems analysts, ecologists, economists, computer specialists and others should sit together and devise methods for the control of pests and diseases by using more than one agent of control so that minimum of natural enemies would be killed. The dosage of the chemicals to be used, their time and frequency of application and the possible after-effects on natural enemies and ultimately the recurrence of the pests, etc. were to be worked out by a systems approach. The quantitative data on the influencing factors was to be computerized to predict the final results. Such an approach could ensure long-range solutions to the problems of pests and diseases, resulting in sustained high yields of crops. Thus, it was realized that even the simplest agroecosystem presented a complicated network of delicately balanced ecological interactions which should not be disturbed by the indiscriminate use of agrochemicals.

To achieve this end, the tool of mathematics was considered useful because it was not possible intuitively to analyse the whole complex of factors involved in the cultivation and growth of a crop, the control of pests and diseases, and to determine the cost/benefit relationship. The modern systems approach to the solution of such problems, therefore, should replace the traditional farmer's approach who, based on his own experience and intuition, was his own systems analyst.

The scientific terminologies and their accepted definitions will further elucidate the various principles involved in pest management.

Agroecosystems

According to NAS (1969) the ecosystems are self-sufficient and self-sustaining habitats where living organisms and the non-living environment interact to exhange energy and matter in a continuing cycle, hence they are self-regulating entities, the examples being forests, ponds, fields, etc. According to Odum (1971) ecosystem is any unit that includes all the organisms (i.e. community) in a given area interacting with physical environment so that a flow of energy leads to clearly defined trophic structure, biotic diversity and material cycles within the ecological system.

The farm lands in which agriculture is practised regularly, represent the agroecosystems, which have less diversity and are intensively manipulated by man. Only a few major species, and numerous minor species live in such a system. Since there is lack of diversity and consequently fewer natural checks, agroecosystems can be more susceptible to pest damage through regular or catastrophic outbreaks. In place of the natural diversity, therefore, agronomic practices can serve as manipulating tools for pest management.

From the ecological point of view, the only good point in favour of agroecosystems seems to be the high intensity of plants per unit area, which to some extent dilutes the damage caused by pests. By the use of tolerant or resistant species and scientifically developed resistant varieties of crops, the plants can withstand pest damage or suppress pest establishment and its further increase. The planning of agroecosystem should, therefore, anticipate the possible pest problems and the ways to solve them through proper pest management.

Pest Management

The use of toxic chemicals for the control of pests increased tremendously during the last few decades. It was realized later that many of these chemicals were not biologically degradable and they not only persisted in the environment but also became concentrated through the food chains. With the consciousness of using the chemicals judiciously to minimize the pollution hazards, the scientists recommended that pests should be controlled by integrating the use of biological agents with the use of insecticides. Based on this concept, Bartlett (1956) coined the term 'Integrated Pest Control' which was defined as the blending of biological control agents with chemical control measures.

Later on in 1961, Geier and Clark advocated the integrated use of all available techniques for the control of insects and not confining only to the biological and chemical methods of control. They suggested that the methods which are considered promising should first be evaluated and, if found effective,be consolidated into a unified programme to manage pest populations. Subsequently, the term 'pest management' was advocated by Geier (1970). Thus, pest management may be considered, an intelligent selection and use of pest control actions, that will ensure optimal economic, ecological and sociological benefits. Pest management includes all approaches ranging from single component control method to the most sophisticated and complex control method. A number of definitions have been proposed for the twin terms of integrated pest control (IPC) and integrated pest management (IPM). According to the expert panel of the Food and Agriculture Organization, integrated pest control may be defined as a system that in the context of the associated environment and the population dynamics of pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains the pest populations at level below those causing economic injury (FAO, 1967).

According to the National Academy of Sciences, IPM refers to an ecological approach in pest management in which all available necessary techniques are consolidated in a unified programme, so that population can be managed in such a manner that economic damage is avoided and adverse side effects are minimized (NAS, 1969).

Smith (1975) defined IPM as a multidisciplinary ecological approach to the management of pest populations, which utilizes a variety of control tactics compatibly in a single co-ordinated pest management system. Dr Ray F. Smith and Dr Perry Adkisson have been awarded the 1997 World Food Prize for their pioneering work on development and implementation of IPM concept.

Pedigo (1991) expanded the FAO definition to lay stress on the importance of socio-economics, and defined IPM as a pest management strategy that, in the socio-economic context of farming systems, the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible, and maintains the pest population levels below those causing economic injury.

Dhaliwal and Arora (2006) defined IPM as a dynamic and constantly evolving approach to crop protection in which all the suitable management tactics and available surveillance and forecasting information are utilized to develop a holistic management programme as part of a sustainable crop production technology.

Based on an analysis of 64 definitions spanning the past 35 years, Kogan (1998) defined IPM as a decision support system for the selection and use of pest control tactics, singly or harmoniously co-ordinated into a management strategy, based on cost/benefit analyses that take into account the interests of and impacts on producers, society and the environment.

A special committee of the National Research Council's Board of Agriculture (NRC, 1996) proposed 'ecologically based pest management' (EBPM), also called 'ecologically based integrated pest management' (EBIPM), emphasizing on some key issues :

- In EBIPM, programmes should emphasize on an understanding of the ecological relationships between the host plant and the management practices like cultural control, biological control and host plant resistance.
- Integration of management practices involves biological (e.g. parasitoids, predators and microbials), chemical (e.g. selective pesticides and pheromones) and cultural (e.g. crop rotation, planting date and aeration)
- Sustainability implies durability over time.
- EBIPM programmes should minimize economic, environmental and health risks.

The idea behind EBIPM is to shift the IPM paradigm from focussing on pest management strategies relying on pesticide management to a systems approach relying primarily on biological knowledge of pests and their interaction with the crops. Hence EBIPM programmes should represent a sustainable approach to manage pests combining biological, chemical, physical and cultural tools to ensure favourable economic, ecological and sociological consequences (Dhaliwal and Koul, 2007).

Huffaker and Croft (1976) have described a series of phases in the evolution of an IPM programme:

(*i*) *Single tactic phase*. Emphasis is generally placed on a single pest utilizing a single tactic. This phase does not represent IPM, but the limitations in this approach may lead to its development.

(*ii*) *Multiple tactic phase*. This phase embraces a variety of tactics (cultural, mechanical, physical, chemical, biological, host resistance, regulatory, etc.) in manipulating pest populations.

(*iii*) *Biological monitoring phase*. This phase introduces monitoring of pest, natural enemies and host plant (phenology) populations as the basis for timing the application of various control tactics.

(*iv*) *Modelling phase*. This involves the conceptualization of the processes involved in pest management systems through mental, pictorial, flowchart and methematical models. As the volume and complexity of data increase, more sophisticated modelling techniques become necessary.

(*v*) *Management or optimization phase*. This process involves the construction of a functional IPM system utilizing compatible subsystems in optimizing the integration of this IPM system with the overall crop production system.

(*vi*) *Systems implementation phase*. This is the ultimate phase through which the optimal systems are unified for delivery to and utilization by the farmer.

The ultimate aim of scientific pest management is to maintain a low level of pest population which would not only maintain the damage lower than the economic injury level but will also support the growth and survival of its natural enemies. The concept is to suppress the pest but not to annihilate it. For that very reason, the broad spectrum insecticides should not be used because they often have the effect of eliminating the pest as well as its natural enemies, thus upsetting the balancing of natural system of insect-parasitoid relationship.

For application in the field it is essential in the first instance to understand the concept of pest management and then to disseminate the knowledge among the practising farmers, translated in terms of their own local conditions and specific farm operations. In other words, the philosophy of pest management is to maintain the population of a potential pest at a sub-threshold level than to eradicate it. This philosphy is based on the observation that every plant can withstand a level of population without showing loss in yield or vigour. However, sometimes an insect may be a vector of a serious plant disease and in that case even extremely low levels of population can be instrumental in complete loss of yield. To understand these concepts more clearly, quantitative measurements are sometimes undertaken which define clearly the degree of damage and allowable damage. These studies include:

Economic Injury Level (EIL)

The critical factor that determines the damaging capacity or otherwise of an insect is its population level. The concept of injury level was propounded to enable us to identify the population at which an insect could cause damage to a crop.

According to Stern *et al.* (1959), it is the lowest pest population density that will cause economic damage. It is the level at which damage can no longer be tolerated and, therefore, at that point or before reaching that level, it is desirable to initiate deliberate control operations.

Although expressed as numbers of insects per unit area, the EIL, in reality, is a level of injury. Because injury is difficult to measure in a field situation, however, number of insects are used as an index of that injury. It may, therefore, be more useful to express EIL in standard units of injury. The standard units of injury are the injury equivalent, *i.e.* the amount of injury that could be produced by one pest through its complete life cycle, and equivalency, *i.e.* total injury equivalents (for a population) at a point of time. If management action (insect supression) can be taken quickly and loss averted completely, EIL may be expressed as follows :

$$\text{EIL} = \frac{\text{C}}{\text{VID}} \qquad ...(1)$$

where EIL = No. of injury equivalents per production unit (insects/ha)

C = Cost of management activity per unit of production (Rs/ha)

V = Market value per unit of product (Rs/kg)

I = Crop injury per pest density

D = Damage per unit injury (kg reduction/ha)

These primary variables are affected by a number of complex variables.

In instances, where some loss from the insect is unavoidable, the relationship becomes

$$\text{EIL} = \frac{\text{C}}{\text{V} \times \text{I} \times \text{D} \times \text{K}} \qquad ...(2)$$

where K represents proportionate reduction in injury (e.g. 0.6 for 60%)

Economic Threshold Level (ETL)

It is the pest density at which control measures should be applied to prevent an increasing pest population from reaching the ecnomic injury level. Control measures are taken at this stage so that the pest does not exceed the ecnomic injury level.

ETL is the best known and most widely used index in making pest management decisions. Although expressed in insect numbers, ETL is, in fact, a time parameter, with pest numbers being used as index for when to implement management strategies. Just as with EILs, ETLs can also be expressed in insect equivalents.

ETL is a complex value based on EIL, population dynamics of the pest, weather forecasting, and pest's potential for injury. The relationship between ETL and EIL is shown in Fig. 9.1. When no action is taken at ETL, population exceeds EIL, while when management steps for pest suppression are taken as the population crosses ETL, the population is forced down before it could reach EIL. ETL is a direct function of EIL and as such is subject to changes in EIL variables. In addition, ETL varies with logistical considerations associated with time delays that may vary from one situation to another.

The concept of EIL and ETL gained wide acceptability from the time it was presented. However, implementation of the concept in practice has been very slow. This is due to a number of serious limitations in the concept. Some of these limitations are given below :

(*i*) The terms EIL and ETL are themselves misleading because both are defined in terms of population densities, while former represents an injury level and the latter the time for taking control measures. This limitation may be overcome by defining these levels in terms of injury equivalents. Moreover, it would then be possible to describe the same type of injury for many pest species.

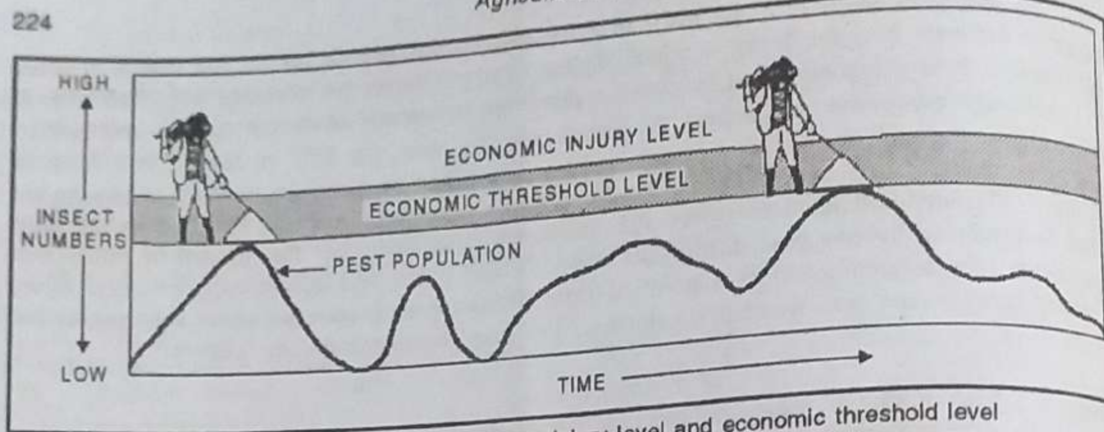

Fig. 9.1 Relationship between economic injury level and economic threshold level

(*ii*) There is a lack of rigorous definition of economic damage, i.e. the amount of injury that will justify the cost of control.

(*iii*) The EIL concept overlooks the influence of other production factors that can affect the crop/pest systems. The externalities left out include interseasonal dynamics, biological relationships with other pests and natural enemies, environmental contamination by pesticides, resistance to pesticides, effect of control in neighbouring fields and health problems relating to pesticides.

(*iv*) Decision levels for management of some types of pests cannot be determined with EILs. Besides medical and veterinary pests, it includes most vectors. It is very difficult to place a monetary value on the reduction in aesthetic value associated with a given type of injury. A similar problem exists with respect to forest pests. Almost all components of EILs are difficult to estimate for forest pests; accurate market values are a problem, management costs may vary greatly and frequently include mere environmental and social costs and the injury/crop response relationships may be difficult to determine because the growth of the crop spans many years.

(*v*) The concept is unsuitable in case of attack of multiple pests on a single crop at the same stage.

However, inspite of these limitations, EIL concept continues to offer a practical approach to pest related decision making in a broad sense. The ETL values for major insect pests of agricultural crops in India are presented in Table 9.1.

Environmental Economic Injury Levels (EEIL)

The challenge of attempting to decrease pesticide inputs further can be met by developing environmentally based EILs and their concomitant ETLs. An environmental EIL is an EIL that evaluates a management tactic based on not only its direct costs and benefits to the user but also its effects on the environment. The EIL equation (equation 2) integrates many management elements, each of which may have a role in making pest management environmentally most sustainable.

(*i*) *Assigning realistic management costs* (*C*). Component C of the EIL equation represents costs associated with taking management action against a pest population, and increased costs cause EIL to increase proportionally. Generally, C does not take into account the environmental costs associated with environmental risks; it is possible to include these costs in variable C of EIL.

Table 9.1 Economic threshold levels (ETLs) of major insect pests of agricultural crops in India

Crop	Insect pest		ETLs
	Common name	Scientific name	
Cash crops			
Cotton	American bollworm	*Helicoverpa armigera* (Hubner)	5-10% infestation in floral forms
	Pink bollworm	*Pectinophora gossypiella* (Saunders)	5-10% infestation in floral forms
	Spotted bollworms	*Earias* spp.	5-10% infestation in floral forms
	Whitefly	*Bemisia tabaci* (Gennadius)	6-8 adults/leaf or appearance of honey dew on 50% plants
	Jassid	*Amrasca biguttula* (Ishida)	Appearance of yellowing and curling on the leaf margins in 50% plants
	Aphid	*Aphis gossypii* (Glover)	Appearance of honey dew on 50% plants
	Thrips	*Thrip tabaci* Lindeman	5-10% infested plants
Sugarcane	Shoot borer	*Chilo infuscatellus* (Snellen)	18-22% shoot damage at tillering phase
Tobacco	Tobacco caterpillar	*Spodoptera litura* (Fabricius)	1-5% incidence
	Whitefly	*B. tabaci*	5-10 adults/leaf
Cereal crops			
Maize	Stem borer	*Chilo partellus* (Swinhoe)	5-10% infestation
	Shoot fly	*Atherigona* spp.	5-10% dead hearts
	Earworm	*H. armigera*	25-30% damage to cobs
Rice	Stem borer	*Scirpophaga incertulas* (Walker)	5% white ears/one egg mass per m^2
	Brown planthopper	*Nilaparvata lugens* (Stal)	10 hoppers/hill
	Gall midge	*Orseolia oryzae* (Wood-Mason)	5-10% silver shoots
	Leaf folder	*Cnaphalocrocis medinalis* (Guenee)	10-15% infested plants
Wheat	Aphid	*Schizaphis graminum* (Rondani)	5-10% infested plants
Fruits			
Grapes	Thrips	*Retithrips syriacus* (Mayet)	20% foliar damage
Mango	Hopper	*Amritodus atkinsoni* (Lethiery)	20% hopper damage in inflorescence
Oranges	Fruitflies	*Carpomyia vesuviana* (Costa)	1-2% incidence
Oilseeds			
Groundnut	Aphids	*Aphis craccivora* (Koch)	5-10 aphids/terminal at seedling stage
	Tobacco caterpillar	*Spodoptera litura* (Fabricius)	20-25% defoliation at 40 days
Rapeseed	Aphid	*Lipaphis erysimi* (Kaltenbach)	50-60 aphids/10 cm terminal portion of central shoot
			0.5-10 cm terminal portion of central shoot covered by aphids
			40-50% infested plants
Sunflower	Gram pod borer	*H. armigera*	One larva/head
Pulses			
Chickpea	Pod borer	*H. armigera*	3 eggs or 2 small larvae/plant
	Cut worm	*Agrotis ipsilon* (Hufnagel)	5% plant mortality
Pigeonpea	Pod borer	*H. armigera*	5 eggs or 3 small larvae/plant
	Leaf webber	*Maruca vitrata* (Geyer)	5 webs/plant
Vegetables			
Brinjal	Fruit and shoot borer	*Leucinodes orbonalis* (Guenee)	1-5% shoot or fruit infestation
Cabbage and cauliflower	Diamondback moth	*Plutella xylostella* (Linnaeus)	1-5% incidence
	Tobacco caterpillar	*S. litura*	1-5% incidence
Tomato	Fruit borer	*H. armigera*	1-5% fruit damage
		H. armigera	One larva/head
		H. armigera	3 eggs or 2 small larvae/plant
		A. ipsilon	5% plant mortality
		Maruca vitrata (Geyer)	5 webs/plant
		L. orbonalis	1-5% shoot or fruit infestation
		Plutella xylostella (Linnaeus)	1-5% incidence
		S. litura	1-5% incidence

Source: Dhaliwal *et al.* (2003)

One approach for estimating environmental costs of pesticides through economic techniques of contigent valuation was presented by Higley and Wintersteen (1992). They estimated the level of risk posed by 32 field crop insecticides to different environmental elements (surface water, ground water, aquatic organisms, birds, mammals, beneficial insects, etc.) and to human health (acute and chronic toxicity). They also estimated from survey data the relative importance of avoiding risk to each of these elements. Additionally, survey respondents (producers) indicated how much they would be willing to pay, in either higher pesticide costs (for safer pesticides) or yield losses, to avoid different levels of risk (high, moderate, low) from a single application of a pesticide. With these data, the individual environmental costs for each insecticide were calculated as below :

$$\text{Environmental EIL} = \frac{PC + EC}{VDIK}$$

(*ii*) *Manipulating crop market value* (*V*). This could be achieved by putting a higher market value for a pesticide–free produce. The extent of increase would depend on the consumer's willingness to pay for a safer product.

(*iii*) *Reducing damage per pest* (*D*). Reducing D implies that less loss of yield occurs for a given amount of injury. This is possible if plant is able to tolerate and compensate for injury. Plants that can tolerate or compensate for injury do not place selection pressures on pest populations. Therefore, the benefits of tolerance and compensation in plant are sustainable and permanent. Even partial tolerance will increase EILs (by decreasing D). The need for pesticides and the risks to environment will be reduced correspondingly.

(*iv*) *Developing environmentally responsible K value*. Modified K is the proportion of total pest injury averted by timely application of a management tactic. Increasing the EIL to improve environmental quality implies that we are willing to tolerate more pests. But this is not always the case. By reducing D or K, EIL can be increased even without causing increased losses or costs.

General Equilibrium Position (GEP)

It is the average population density of a pest over a long period of time unaffected by the temporary interventions of pest control. The population fluctuates around a mean level as an outcome of the influence of density dependent factors, such as parasitoids, predators, diseases, etc.

It may be understood that EIL may be at any level from well below to well above the GEP. In certain insects GEP is well below the EIL or even ETL and never reaches the latter two parameters. Such insects are rarely noticed physically but the damage caused by them through the introduction of a virus or any other disease can be most significant.

GEP touches EIL and ETL, approximately 2 to 5 years for many insect pest species. Such insects are called 'occasional pests'. The increase in population may be due to the injurious effect of pesticides or due to favourable weather conditions. For example, in Punjab, outbreaks of the armyworm, *Mythimna separata* (Walker), on wheat, are recorded every 2 to 5 years.

Sometimes, the control measures are required frequently to bring down the GEP well below the EIL and ETL. Such a situation has been observed in the tobacco caterpillar, *Spodoptera litura* (Fabricius), which is a 'regular pest' of cruciferous vegetables.

The known severe pests form another category altogether and, in their case, EIL and ETL are below the GEP level. The maize borer, *Chilo partellus* (Swinhoe), is a severe pest of maize and its severity increases in some Himalayan valleys where the climate is mild. Moreover, it is much more severe on the hybrid corn varieties than on the local, comparatively low yielding maize.

Cost/Benefit and Benefit/Risk

As we improve the capability for predicting pest appearance, we can determine precisely the ETLs, and know exactly when to apply control measures. There is a need to emphasize costs and benefits. The preparation of crop life tables provides a solid foundation for analysis of pest damage and, cost/benefit ratio in pest management. If a crop is grown more than once in a year in the same field we should work out the crop-season life tables. In most pest control activities, the benefits are usually not known, because those cannot be measured, hence the cost of prevention becomes the cost of production. In other words, the use of pesticides can rarely contribute to increase in yield and, at best, it can prevent the loss of yield, making the benefit both indirect and incalculable.

Benefit/risk analysis provides the means for assessing relevant economics versus risks in pest control. The judicious use of insecticides should be the philosophy of pest management. It is estimated that, generally, 1 per cent of the insecticide applied,reaches the target pest and the rest merely contaminates the environment as residue or causes mortality of the non-target or even useful species. Some non-degradable insecticides, such as the chlorinated hydrocarbons, attain biological magnification in the environment through food chains. Thus, a grower while ensuring safety in handling and applying a higher toxic pesticide, should also consider its injurious effects in the environment.

INTEGRATION OF TACTICS

The pest management tactics are either preventive or therapeutic. Preventive practice utilizes tactics to lower environmental carrying capacity (reduce the general equilibrium position) or increase tolerance of the host to pest injury. Prevention relies on an intimate understanding of the pest life cycle, behaviour and ecology. The preventive tactics involve natural enemies, host resistance and cultural practices.In addition, quarantines are also an important component of preventive tactics. Therapeutic tactics are applied as a correction to the system when necessary. The objective of therapy is to dampen pest population below EIL. The only widely used therapeutic tactic is the use of conventional insecticides but other approaches like microbial agents, augmentation of natural enemies, use of insect growth regulators, etc. also play a vital role.

Actual integration involves proper choice of compatible tactics and blending them so that each component potentiates or complements the other. Probably, the earliest example of integration of techniques was the use of a combination of resistant varieties and sanitation practices as prophylactic measures combined with application of calcium arsenate at high population level in case of boll weevil on cotton in USA in early 1920s. Similar programmes were being developed for other pests also but the advent of synthetic organic insecticides intervened and these techniques were relegated to the background. The misuses and abuses of insecticides have again focused our attention on integrated control measures.

Rhodes grass scale, *Antonina graminis* (Maskell) is a cosmopolitan insect feeding on over 100 hosts including 38 species of range grasses in Texas. A parasite introduced from India, *Neodusmetia sangwani* (Subba Rao), was successfully established against the pest in Texas. However, during the June population peak of the pest, natural enemy population was lower due to general host unsuitability during May. The resistant Rhodes grass variety 'Bell' was found to tolerate pest attack without appreciable damage. This variety, thus, provided relief until the parasite effectively reduced scale populations. The predation rate was highest on resistant cultivars and this was attributed to the greater movement of hoppers in search of suitable feeding sites

It has been found that the rate of parasitism by *Bracon mellitor* Say, the most important native parasite of boll weevil, *Anthonomus grandis* Boheman was higher on frego bract (resistant) than on normal bract (susceptible cotton). The mortality of *Nephotettix virescens* (Distant) has been found to be highest and population lowest when resistant varieties IR 26 and IR 56 were combined with predators, myrid bug, *Cyrtorhinus lividipennis* Reuter and spider, *Lycosa pseudoannulata* (Bosenberg & Strand). The feeding of *Helicoverpa zea* (Boddie) on ED73-371, a soybean genotype resistant to the Mexican bean beetle, *Epilachna varivestis* Mulsant increased its susceptibility to *Bacillus thuringiensis* Berliner. Thus, *Bt* which is normally ineffective against *H.zea* might be effective on resistant soybean.

Natural control by parasitoids and predators can be greatly strengthened by use of a large number of cultural practices like intercropping, trap cropping, strip harvesting, etc. Modification of the crop environment by manipulation of irrigation, fertilizer, row spacing, seed rate and tillage operations, etc. may also lead to substantial improvement in benefits of biological control. A combination of moderate resistance to carrot fly, *Psila rosae* (Fabricius), with specific sowing and harvesting dates, has enabled satisfactory yield of marketable carrots in heavily infested fields. The effect of plant resistance,planting dates and tillage practices was complementary in reducing greenbug, *Schizaphis graminum* (Rondani) population on sorghum; the resistant hybrids coupled with late planting dates and no tillage have been consistently effective for controlling the pest.

Combining plant resistance with well timed lower dosages of insecticides can sometimes achieve adequate pest suppression while reducing otherwise high insecticide inputs. Sweet corn hybrids resistant to corn earworm require less insecticide than susceptible hybrids to obtain an equivalent reduction in pest incidence. The insecticide rates on an insect-resistant groundnut cultivar (NC 6) can be reduced by 75-80 per cent against *Diabrotica undecimpunctata howardi* Barber and 60 per cent against *Frankliniella fusca* (Hinds).

Insect pest management in cotton in Texas is a good example of integration of different tactics. The foundation of the programme begins with preventive tactics aimed at boll weevils. The basic tactic in prevention is a return to early planting of short season cotton cultivars, moderate fertilizer use and well timed irrigation. Plant thinning is delayed or not implemented, which suppresses vegetative growth and stimulates early fruiting. These practices shorten the production season and period of vulnerability to insects. Early harvesting, stalk destruction and use of defoliants late in the season prevent further weevil production and weaken or starve weevils going into hibernation. Pest surveillance and therapeutic treatments with organophosphates against boll weevil and flea hopper, *Psallus seriatus* (Reuter) are used at ETLs. Pyrethroids are applied in case of *Heliothis* outbreaks.

The Indian Institute of Horticultural Research has developed IPM in cabbage and tomato by employing trap cropping and biopesticides. Growing of Indian mustard in paired rows at the beginning and after every 25 rows of cabbage attracted more than 80 per cent of diamondback moth infestation besides almost entire population of leafwebber, stem borer, bugs and aphids. To control the remaining attack of diamondback moth, a 4 per cent neem seed kernel extract (NSKE) is applied at primordial or head initiation stage of the crop. Similarly, trap cropping of marigold after every 8 rows of tomato attracts most of the ovipositing moths of *Helicoverpa armigera* (Hubner) to the former crop. The use of conventional insecticides on the trap crop reduces their attractiveness to the pest. Therefore, the pest on the trap crop has to be removed mechanically. The residual pest population on both the crops is controlled by sprays of *H. armigera* NPV @ 500 larval equivalent per ha.

PRE-REQUISITES FOR DECISION MAKING

There are certain essential pre-requisites which must be followed before deciding to employ the pest management options.

1. Correct identification of pest. The correct identification of the pest is the first most important step on which the next course of action depends. Mis-identification of a pest can lead to complication of the problem rather than solving it. Efforts should be made to identify a pest up to species level as closely related species differ with respect to several biological parameters.

2. Life cycle. The knowledge of the sequence of developmental stages (egg to adult), their duration, number of generations and method of overwintering is essential to know the 'weakest link' in the life cycle. This would help to aim control measures effectively at the most vulnerable stage of the pest.

3. Habits. The important features of habits of pests which have a bearing on their control include the developmental stages responsible for plant injury, mode of feeding, parts of the plants attacked and whether the pest feeds externally or bores into the plant. Moreover, it is essential to know whether the pest transmits any disease in addition to causing direct injury to the plant.

4. Host range. It is essential to know whether the pest is monophagous (feeds only on one host plant), oligophagous (feeds on several plant species) or polyphagous (feeds on many plant species). Moreover, the non-cultivated plants which may act as reservoir of infestation should also be known. Plant host range can help to decide the proper crop rotation to be followed to keep the pest under check.

5. Natural regulating factors. Some pests can be kept under check by the activity of natural controlling factors like parasitoids, predators and disease organisms. Their precise role in specific circumstances should be understood to make the best use of natural mortality factors and their integration with other control measures.

6. Reinfestation. It is important to know the capacity of a pest to re-infest an area following its elimination. Some pests are highly mobile and quick fliers, and capable of rapidly re-invading the area. In contrast, some pests have very limited capacity to move and are very slow to reinvest.

7. Crop value. Expenditure on control measures can only be justified when increase in marketable yield of the crop produced is worth more than the cost of the control. Control measures should, therefore, only be initiated when they are economically justifiable. Usually, costly controls can be applied more logically to florist and fruit crops than to field crops.

8. Consumer pressure. Consumer demands have an important bearing on pest control. Certain fruits and vegetables may be rejected by the processor by mere presence of one or more insects in the samples of the produce. Similarly, even slight blemishes may not be tolerated on certain top-grade fruits.

9. Survey and detection. It is essential to carry out regular monitoring surveys to detect low-level pest infestations before they become damaging. It would help in devising strategies to prevent the pests to reach damaging levels. If the pest population tends to grow beyond damage threshold, appropriate control measures can be undertaken.

10. Selection of management options. The choice of appropriate option is very critical for the successful management of the pest. Before resorting to chemical control, the possibility of employing natural control agents, cultural practices and resistant varieties should be explored. If insecticides are to be used, information on their toxicity, cost, effectiveness, formulation, method and time of application, and their impact on beneficial arthropods in agroecosystem must be known.

DECISION MAKING

Decision making in pest management, like all other economic problems, involves allocating scarce resources to meet human needs. Initially, there is the choice of whether, when and how to attempt to manage insects and other pests with scarce capital or labour. Other resources may be scarce, however, such as pesticide-susceptible insect strains, an uncontaminated environment or information on the extent of pest infestation may also affect the desirability of particular choices.

Decision makers in IPM exist at many levels, from farmers, managers and contractors, each of whom are concerned with single fields, to industry and government personnel who are concerned with regional or national policies. Decision making at any of these levels would require generation of information on the following aspects :

(*i*) *Fundamental information*, concerned with basic technical, biological and ecological processes that affect the damage caused by pests and the effectiveness of control measures.

(*ii*) *Historical information*, in the form of records of previous pest incidence and damage, used to indicate trends in pest development and to assess the probability of future attacks.

(*iii*) *Real-time information*, collected by on-farm monitoring schemes or by regional surveillance and concerns on current pest status. Real time information on pest attack and damage can be obtained by direct assessment or indirectly through meteorological measurements.

(*iv*) *Forecast information*, involving estimates of future levels of attack and damage. This can be obtained by combining the previous categories of information often by means of a regression or more complex model.

The information so generated is analysed for the purpose of decision-making. This requires the use of decision making techniques like linear programming, goal programming, simulation modelling, decision trees and dynamic programming. As the information based on various aspects of pest management increasd dramatically, computers were used first to process data and information followed by knowledge processing and decision making. Computer based systems could be used to provide access to information by serving as a cache, integrate and synchronize the information for use, interpret the information and serve as implementation coach.

IMPLEMENTATION STRATEGY

The development of an implementation strategy should not be left to the final phases of any IPM programme. It should initially be considered during problem formulation and then continually readdressed throughout the research phase of the programme. The two factors essential for the implementation of most IPM programmes, *i.e.* farmers' participation and the legislative measures are discussed below.

Farmers' Participation

To be effective and economically feasible, implementation of IPM at the farm level requires a degree of training, experience and attention to individual field conditions beyond the capabilities of most farmers, who must devote most of their time and energy to other aspects of crop production. On the other hand, top-down extension perpetuates an ideology of elitism, paternalism/passivity and social control. There is, thus, a need for a relationship of equality and dialogue between extension agent and farmer such that the partial knowledge of each is combined to solve problems and bring about positive change more effectively.

Since it is relatively complex, location specific and management-intensive, IPM is an educational challenge. The farmer must learn the principles and acquire the knowledge and skills necessary to make autonomous decisions based on specific farm conditions. There is a need for farmers' participation at every step of the R & D process in order to draw on farmers' intimate understanding of local conditions and constraints, their innovativeness and their skill at making the best possible living using limited resources.

Agricultural specialists should not dominate but instead should act as consultants, facilitators and collaborators, simulating and empowering farmers to analyse their own situation, to experiment and to make constructive choices. Extension agents should teach them analysis and decision making process. Placing the farmer at the centre of the technology development process is wholly consistent with the IPM goal of making the farmer a confident manager and decision maker, free from dependence on a constant stream of pest control instructions from outside.

An innovative approach recently applied for the implementation of IPM programmes is the 'Farmer First' approach which is being used for IPM on rice in Indonesia. In this method, farmers are divided into small groups to monitor the crop and then each group analyses the field situation by identifying the key factors. Group members then decide whether any action is required. At a combined meeting, each group presents and defends its summary to other trainees. The trainer facilitates by asking leading questions or adding technical information if necessary. This process allows farmers to integrate and practise their skills and knowledge, and gives trainers an oppurtunity to evaluate the trainees' ability. Thousands of farmers have been trained utilizing this approach and it is being tried on a pilot scale. A survey among these farmers during the first post-training season revealed that they really decreased their frequency of pesticide sprays to a level consistently lower than that of non-IPM farmers. The percentage of farmers not applying pesticides was also significantly higher among the trained ones. Inspite of lower pest control expenditures, these farmers obtained higher yield than the non-IPM farmers. Other viable and easily implementable approaches need to be developed locally taking into account small holding size, low income and general literacy level of the average farmer in the area.

Legislative Measures

IPM is an information system and its adoption reduces pest control costs. The alternative to IPM is the indiscriminate use of broad spectrum synthetic organic pesticides. Unfortunately, while pesticide manufacturers and users (farmers) derive the full benefits from the use of these chemicals, they pass on the environmental and ecological costs of their use to the society as a whole. If they are made to bear the full cost of the use of these toxicants, they may find IPM a more economical and attractive alternative. This could be achieved by enforcing suitable legislative measures.

Secondly, in order for an IPM programme to be successful, it must be followed by most, if not all, farmers in a geographical area. Ideally, all farmers may adopt an IPM programme voluntarily but some farmers may hold out. Such farmers called 'spoiler holdouts' may impair the success of a programme by failing to adopt a necessary practice. Legislative measures are required to impose the programmes upon an unwilling minority.

Thirdly, the importance and benefits of pesticides are being overemphasized by a multibillion dollar industry utilizing the services of not only their salesmen but also agricultural scientists, administrators and planners. There is not yet a strong market in IPM information. Much important information which might induce a farmer to adopt IPM is not immediately observable and is, therefore, not sought by him. A manufacturer has no incentive to recommend a programme that uses less pesticides or even selective pesticides that kill a limited range of pests. This distortion could only be corrected by legislative action.

FRAMEWORK OF IPM PROGRAMME

There has been a widespread tendency to work within specialized subject areas of IPM and this movement towards specialization among researchers has now reached its peak of ascendancy. The need now is to place this specialist knowledge, abilities and skills within a broader scientific framework. There ought to be better coordination and exploitation of this valuable resource. This means that work of specialist groups dealing with different aspects of a common problem of insect pest control needs to be coordinated and placed in the context of the framework of an integrated pest management programme. This integration needs to be started at the top, in funding policy and reach up to the lowest level, in implementation.

(*i*) The funding authorities need to develop a coherent policy and ensure that all individual research groups working on similar cropping systems coordinate their approaches. There is a need to allocate funds for development of complete pest management programmes.

(*ii*) Secondly, there is an urgent need to develop conceptual and theoretical framework for IPM. The present situation is that IPM is made up of a great many isolated parts, each of which can be developed internally but which is not clearly connected to anything else, *e.g.* farming systems, host plant resistance, natural enemies and decision-making behaviour. These pieces ought to be combined in an integrated programme. This requires a theoretical framework that will provide guidelines for pest managers. The framework will incorporate pest outbreak theory, a classification of pest types, their hosts and farming systems, and to identify options most appropriate for management strategies.

(*ii*) Thirdly, integrative level of research in the form of field trials to test combination of control options for their compatibility and effectiveness is essential. This integrative research will require the combined input of all relevant disciplines to design, carry out and analyze the data from suitable factorial or multifactorial experiments. These experimental designs will be necessary to assess the interaction between the various treatments under test and arrive at a combination of options that produce higher yields.

(*iv*) Fourthly, integration is required at the level of organizational behaviour. It is important that appropriate organizational structures are developed because they are fundamental to good management. Without them, integration of research will be less likely to occur and at a different level it may be found to affect motivation, innovation, morale and decision making, and exacerbate conflict and poor coordination.

(*v*) Ideally, IPM should involve integration of control options for the management of all types of pests and not just insects. Insect pest management will then just be a subsystem of integrated pest management (IPM). This will require multidisciplinary research encompassing insects, pathogens, weeds and other pests. The importance of integrating the control of insects and pathogens is illustrated by an early story involving control of grape phylloxera on grapes in Europe. This example is often cited to illustrate the importance of plant resistance. The other part of the story is not so well known. Ironically, plants introduced from North America carried the pathogen of *Plasmopara viticola*, the causal agent of downy mildew to which European grapes were highly susceptible. The American root stock saved French vineyards from grape phylloxera but exposed them to an even more dangerous risk. The devastating epidemic of downy mildew that followed threatened wine production throughout Europe. Ultimately, the development of Bordeaux mixture,an early fungicide against the pathogen, saved European vineyards. This example underlines the need to consider the whole pest complex and the implications of any management strategy.

(*vi*) Lastly, the development of an implementation strategy should not be left to the final phases of a research programme. It should initially be considered during problem formulation and then continually readdressed througout the research phase of the programme because it is often at the point of implementation that many pest management programmes fail.

PERSPECTIVES IN IPM

The strategy of exclusive reliance on insecticides for all pest problems created a number of ecological and environmental problems. We now know that insects possess a remarkable ability to survive in the face of selection pressure exerted by insecticides and other forms of pest control. To overcome these problems, integrated pest management based on ecological principles was developed as a viable and attractive alternative. Though the concept of IPM has been universally accepted, there are as yet few IPM programmes functioning at the farmers' level.

A major limitation is the lack of a theoretical framework into which various components of IPM can be fitted to develop a viable IPM system. There is an urgent need to develop IPM systems for different crops, which are environmentally benign, conserve our plant and animal genetic resources and are economically viable. This requires intensified research efforts in formulation, research and implementation phases of the IPM programmes.

The insecticides will continue to be essential components in most of the IPM programmes but their use must be based on the concept of ETLs. With rapid development of insecticide resistance and widespread occurrence of multiple and cross resistance,insecticide resistance management (IRM) should also form an integral part of all IPM programmes. Methodology for monitoring of insect pests and natural enemies needs to be refined to obtain more accurate information. Development of mathematical models will help in predicting outbreaks of important pests. Newer approaches based on biotechnological tools must be exploited for the development of insect-resistant varieties and biopesticides. The role of allelochemicals and other substances in insect-plant interactions needs to be studied in case of different insect pests. Tritrophic interaction involving natural enemies, phytophagous insects and host plants should also be utilized for increasing the effectiveness of natural enemies. Development of technology for mass production of promising parasitoids, predators and pathogens is essential for their large scale utilization. Lastly, the farmers need to be convinced of the benefits of IPM programmes so that these are implemented in true letter and spirit. Innovations in farmers' participation and training can help to overcome many of the implementation problems.

one another, it is called intra-specific competition.

b) When the individuals of different species compete one another, it is called inter-specific competition.

The above both types of competitions reduce the insect population.

ii) **Parasites and Predators:**

Parasite: The insects which live either on or in the body of other insects for getting food are called parasites. It means, the parasites are of two types:

a) Parasites which live on the body of insect are called ectoparasites or external parasites.

c) Parasites which live in the body of other insects are called endoparasites or internal parasites.

The insects on which the parasites are living are called hosts.

Predator: The insects which catch and eat away the other insects are called predators. The insects which are eaten by the predators are called preys.

Both the parasites and predators are harmful to insects and greatly reduce their population.

iii) Diseases: Many organisms like protozoa, bacteria, nematodes, fungi,, virus etc., cause diseases in the insects and kill them and thus greatly reduce their population.

METHODS OF INSECT CONTROL

Insect control in its broad sense includes everything that makes life hard for insects and tends to kill them and to prevent their increase or spread over. The insect control implies the regulation of insect activity with the best the interest of man. There are two main methods of insect control:

1. NATURAL CONTROL /Effect less Control

All control measures, which are in the hands of nature, collectively constitute natural control. Natural control has the following types:

i) Weather factors: e.g., Temperature, humidity, light, rainfall, hail storm, wind etc.

ii) Topographical features: e.g., Mountains, oceans, lakes, deserts, rivers etc.

iii) Parasites and Predators: Both parasites and predators take their food form other insects and thus harm or kill them.

iv) Diseases: Many organisms cause diseases in the insects and kill them.

2. **ARTIFICAL OR APPLIED CONTROL** Applied by human.

It has the following types:

i) Cultural or agricultural control
ii) Physical control
iii) Mechanical control
iv) Biological control
v) Reproductive or genetic control
vi) Legal control or legislative control
vii) Chemical control
viii) Integrated pest management.

I. **CULTURAL OR AGRICULTURAL CONTROL**

It is the control of insect pests by performing ordinary agricultural practices or operations. The following farm operations can control the insect pests attacking various crops.

1. **Ploughing:** Certain insect pests like crickets and grubs of beetles are exposed in the sun by ploughing and thus they are eaten by the birds. By ploughing the insect hibernating in the soil are also exposed to birds etc., and thus they are controlled.

2. **Hoeing or Interculture:** Hoeing or inter-culture can also destroy certain insect pests e.g., the eggs of mango mealy bug can be destroyed by hoeing under the mango trees. By hoeing, the eggs are exposed to sun and also eaten by birds and ants. Similarly, by interculturing the crops, various insects and their eggs present in the soil are exposed to birds etc.

3. **Manuring:** By putting fertilizer in the field, we make the crop more healthy and vigorous. Such a crop can resist or

withstand the attack of various insect pests. So, manuring or fertilizing has an indirect upon the insects.

4. **Irrigation or Watering:** By irrigating the fields, certain insect pests like crickets attacking the cotton seedlings and the white ants attacking cotton, sugarcane, chilies etc. can be driven out of the field and thus the crop can be saved.

5. **Clean Culture of Eradication of weeds:** The crops, which are not cleaned and are full of weeds, are seriously attacked by some insect pests For keeping the insects away from the crop, the farmers should not allow the weeds to grow in their field. Some weeds act as food plants and egg laying places for the insects like army worms and hairy caterpillars.

6. **Removal of stubbles:** Stubbles of various crops like sugarcane, rice and maize should be uprooted because the borers of these crops hibernate or hide themselves in these stubbles.

7. **Removal of affected crop plants and the fallen fruits:** When there is attack of top borers of sugarcane at an earlier stage of the crop, the damaged tops of the canes can be pulled out along with the attacking insects. Similarly when there is an attack of Gurdaspur borer in the sugarcane, the affected portions should be cut away to reduce the population of the insects. In the fallen fruits of trees, the maggots of flies are present. By collecting such fallen fruits and destroying them by burning or by burying them in the soil, the attack of the fruit flies can be reduced. This practice of removing the affected plants can be done also in rice crop against the attack of rice borers.

8. **Crop rotation:** You should not grow a single crop year after year in the same field because the insects attacking a particular crop remain hibernated in the soil or stubbles, and attack the crop when it is sown there in the

next year. This thing has been especially observed in case of sugarcane borers, rice borers, maize borers etc. If the sugarcane is sown every year after cotton, if gets the high attack of white ants or termites.

9. **Sowing of resistant varieties:** The susceptible varieties of crops get the high attack of insect pests whereas the resistant varieties are least affected by them. At present we do not have any absolutely resistant variety of a crop but many varieties of crops have a comparative resistance to an insect pest. Hairy cotton varieties are more resistant to the attack of sucking pests like cotton jassid, cotton whitefly etc., than the non-hairy varieties. The cane varieties with hard skin or epidermis are more resistant to the attack of sugar cane borers than the varieties which have a soft skin. The Basmati variety of rice is highly susceptible to the attack of rice borers than the IRRI varieties of rice which are least attacked by the borers. Similarly the rice Basmati variety is comparatively resistant to the attack of rice leaf hoppers than the IRRI varieties which are highly susceptible to the attack of these leaf hoppers.

10. **Growing of trap crops:** Growing of Bhindi along the outer border or in the neighborhood of cotton crop will greatly attract the cotton jassid and spotted boll worm of cotton and thus cotton crop will be saved from the attack of these insects. Similarly, arhar crop can be sown along the outer borders of the cotton crop to attract the cotton weeil, and thus the crop can be saved from this pest. If you like, you can control cotton weevil on arhar crop by spraying.

II PHYSICAL CONTROL

It is practicised by the manipulation of physical factors of the environment by man. The following physical factors are used for the control of insect pests:

1. **Temperature:**

The insects can carry out their development and activity at a particular level of temperature (optimum temp.) If the temperature increases or decreases, the insects can't perform their normal activities.- If the temperature becomes very high or very, low. The insects are altogether killed.

i) **Use of Solar Energy or Radiant Energy:** In Pakistan, it is a common practice to spread the infested grains in the sun heat for killing Khapra etc.

ii) **Use of high temperature:** All stored grain pests in the stores can be killed by maintaining a very high temperature of 52-54oC with the help of heating pipes. By this method, all insect pests are killed within three hours.

iii) **Use of low temperature:** It is common practice to keep the food products (especially potatoes) in a cold storage to avoid the attack of insect pests. The temperature of cold storage is about 4 °C; and at 0 °C below insects cannot attack the stored products.

2. **Humidity:**

Like temperature, there is an optimum level of humidity at which insects can carry out their growth and development. At very high or very low humidities, the insects cannot carry out their normal activity and they are killed (High humidity can be obtained by heavy irrigations, and low humidity can be obtained by P2O5 application, sun drying etc.

3. **Light:**

Light had been used for the control of many insect pests in the form of light traps. If we hang a bulb or a lamp in the field at night time, most of the insects like moths, beetles, crickets and grasshoppers will be attracted towards this light. We place a container of kerosene oil below the source of light. When the insects are attracted towards this light, they first strike the source of light and then fall down in the container. Thus they are killed and the crop is saved from these insects. Light is also being used in the form of radiation energy or nuclear energy to kill or sterile the insects. When the insects are treated, they become sterile and are incapable of further reproduction.

4. **Sound:**

High intensity sounds are used to save the crops from the damage of certain insect pests. For this purpose drums are beaten to avoid the sitting of locusts on the plants.

III MECHANICAL CONTROL

It is the control of insect pest, by special devices, machinery and manual operations which are only meant for killing the insects. The following mechanical devices are done to control the insects:

1. **Hand Picking:**

It is the picking up of insects with human hand and then killing them by some method. In this case e.g., the eggs, sluggish larvae, and adults of certain insects are picked up and then destroyed e.g., egg pods of mango mealy bug which are laid under the mango trees and are collected by hands and destroyed.

2. **Netting or bagging:**

Some insect pests are collected with insect collecting hand nets or with very large field bages and then they are killed by some method e.g., rice grasshoppers, rice bugs.

3. **Trapping:**

There are many types of traps which are used for killing insects. The turnips are chopped and heaped in the fields where there are cutworms. During night time, cutworms come out to damage the crop, and at day time, they hide in those chopped potatoes or turnips. During day time, we can collect the cut-worms from these hiding places and kill them. Pheromone traps are also used for killing cotton boll worms and fruit flies. Light traps are used for killing many insects especially the adults of sugarcane, rice, cotton and maize borers.

4. **Physical Barriers:**

In old times, physical barriers like construction of mud walls, digging of deep trenches around the fields and filling them with water or using of tin sheets or iron sheets around tne field, were used to check the entry of army-worms, locust, hoppers etc.

5. **Physical beating:**

In old times, some insects were killed by physical beating e.g., locust, flies are killed by this method.

6. **Rope dragging:**

Some insects are killed by rope dragging. When there is attack of boll worms on cotton crop, two men drag a rope over the crop, in doing so the infested bolls fell down on the ground. Later on , the field is irrigated and the bollworms present in the bolls on the ground are drowned in the irrigation water.

7. **Use of bands:**

There are many types of bands which are used for killing the insects. Out of these bands, the following two are worth mentioning:

i) **Sticky Band:** Any sticky material can be used around the tree trunks in fruit orchards to prevent the insects from climbing up the tree. At present, two types of sticky materials or bands are being used against the mango mealybug.

ii) Ostico Sticky Band is imported from America.

iii) Nimhar Sticky Band is prepared from following materials.

1 lb of castor oil

1lb of conc. H_2SO_4

2 lbs of rosin powder

All these things are mixed and boiled, and at the end some glycerin and calcium chloride are added to it. This preparation is used at the rate of I Ib for 10-20 trees. it remains effective for a week against mango mealy bug nymphs and females.

ii) Slippery Band: In this case, slippery cloth like oil cloth or polythene sheet is used around the tree trunks which stop the upward climbing of the pests.

iv. BIOLOGICAL CONTROL

It is the control of insect pest by encouraging and utilizing living organisms by man. There are four methods of biological control:

1. By importing parasites and predators from abroad and then releasing them locally against a particular insect pest.
2. By collecting parasites and predators from one part of the country and releasing them in an other part of the country at the time of need.
3. By rearing parasites and predators in large numbers in the laboratory and then releasing them outside in the field against a particular pest.
4. By collecting parasitized stages of a particular pest (egg, larva and pupa) for emerging of parasites in the laboratory and then releasing them in the field against that particular pest.

The bilogical control can be done with the biological control agents or many living organisms such as Entomophagous insects, birds (e.g., sparrows, starling, rosy pestor etc.)

Entomophagous Insects

The insects which feed upon other insects are called entomophagous insects. These are of two types:

i) Parasites ii) Predators

i) Parasites: The insects living or in the body of other insects are called parasites. The insects, on which parasites live, are called hosts. Parasites are of two types:

a) Ectoparasites: Which live on the body of insects.
b) Endoparasites: Which live in the body of insects.

The act of parasitizing insects is called parasitism. The parasites may be primary parasites, secondary parasites or tertiary parasites. The parasites living on parasites are called hyperparasites and this process is known as hyerparasitism e.g., Aphelinus mali is a parasite which controls successfully the wooly apple aphids on apples. Some other parasites of cotton bollworms are Apenteles. Sp. Bracon greeni.

ii) Predators: The insects which catch and feed upon other insects are called predators. The insects on which they feed are called preys e.g., Lady bird beetle and chrysopa are predators which successfully controls aphids.

Difference between Predator and Parasite

PREDATORS	PARASITES
The insects that catch, tear, bite and eat in a single meal, the insects which are smaller, weaker and less intelligent.	The insects that live on or in the body of insects (host) which are stronger and more intelligent.
Obtain ther food directly.	Obtain their food indirectly
Independent of the habitat.	Same habitat as of host.
Each eats many individuals before maturity.	Feeds on a single individual till maturity.

sect

Important Predators

	Predator
1.	Preying mantis
2.	Chrysopa
3.	Lady bird beetle
4.	Dragonfly
5.	Water bug

6.	Antlion
7.	Beetles e.g., dytiscus sp. Coccinella sp.

Important Parasites

1. *Goryphus mursi* (parasite of cotton boll-worms0, Family Braconidae. Order: Hymenoptera.
2. Family Echniomonidae, Order: hymenoptera (parasites of cotton boll-worm and parasites of sugarcance top borer.
3. Apentles sp. (parasites of Lepidopterus larvae.)

IV. LEGISLATIVE CONTROL

It is the control of insect pest by enacting and enforcing insect laws, by the Government. There are four types of insect laws in Pakistan like other countries of the world. These are:

1. Legislation preventing the entry of pests from foreign countries (quarantine laws).
2. Legislation preventing the spread of pest within the country.
3. Legislation regarding the control of established pests.
4. Legislation governing manufacture and sale of insecticides.

1. **Quarantine Laws** To check the import and Export of goods

Quarantine laws are those which govern the import and export of an agriculture commodity to ensure that it is insect free.

The following quarantine laws and other insect laws have been framed by the government in the sub-continent and our country from time to time:

i) Pest Act of 1906 for checking the entry of mexican cotton boll weevil.

ii) Destructive Insects and Pests Act II of 1914. It still exists in our country.

iii) Regulatory Order of 1940 for preventing the spread of sanjose scale of apples in the Punjab Province.

2. **Insect Legislation in Pakistan**

i) **Before one unit**

a) In Punjab province, there was "The Punjab Destructive Insect Pest Disease and Weed Control Act of 1959".

b) In Sind Province, "The Sind Boll-worm Act of 1947" to control boll-worm.

c) In N.W.F.P., "The N.W.F.P. Sugarcane Pyrilla Act of 1950" to control the sugarcane pyrilla.

ii) **After one unit**

The West Pakistan Agricultural Pests Ordinance of 1959 for controlling all serious pests of major crops. The Government of Punjab has amended Rule-I of this ordinance in 1971-72 According to this amendment, no occupier of any land shall sow Basmati or IRRI rice nurseries earlier than 20th May, or transplant the nurseries later than 7th August.

Vi REPRODUCTIVE OR GENETIC CONTROL

It is the control of insect pests by releasing sterilized males into their natural populations in the fields. This method consists of:

1. Rearing the insects in large number.
2. Sterilizing them and
3. Releasing them in the field in their natural populations.

STERILIZING THE INSECTS

The insects can be sterilized by radiation, certain chemicals and hybridization.

i) **Sterilization by Radiation**

The insects can be sterilized by exposing them to alpha, beta and x-rays, but gamma rays have proved to be the best. For gamma radiation, Co 60 and Cs 137 are commonly used. Generally the dose of radiation is 5000-60,000 radiations. Any stage of the insect like egg, larvae, pupa and adult can be irradiated. The pests like guava fruit-fly, melon fruit-fly, oriental fruit-fly, cabbage looper etc., have been controlled by this method.

ii) **Sterilization by chemicals**

The chemicals used for the sterilization are organo metals, DMF, Tepa, Metapa hempa, Colchicine etc. these chemicals can be applied to the insects orally, by injection, by spraying etc.

iii) **Hybrid sterility**

When two closely related species are crossed, the hybrids are all sterile just like a mule. This is called hybrid sterility. Midterm

VII. CHEMICAL CONTROL

Chemical control is the control of insect pests with the help of pesticides.

PESTICIDE

Any substance or mixture of substance intended for preventing, killing, repelling or controlling any organism which is declared pest.

Classification of Pesticides

Pesticides can be claassified as:

Pisicides ⇒ Fishes

A. Insecticides.
B. Rodenticides.
C. Acaricides. ⇒ To control the Mites.
D. Weedicides.
E. Fungicideds.

Avicides ⇒ To control bi

A. INSECTICIDES

Any material that disrupts he vital processes of insects by chemical action is called an insecticide.

Classification of Insecticides

Classification can be done according to following:

1. Mode of Entry.
2. Mode of Action.
3. Mode of chemical Nature.

I. MODE OF ENTRY

1. Stomach Insecticides

These insecticides are applied on the plants when the chewing insects eat the plants. The insecticides along with food enter into stomach and kill the insect by chemical action.

2. **Contact Insecticides**

These insecticides are applied directly on the insects when they are damaging the crops. Such insecticides when come in contract with the body wall of the insects, enter the body through the body wall. These insecticides are used against sucking insects.

3. **Systemic Insecticides**

These insecticides are applied through the soil and by spraying. They are absorbed by the roots and other parts of plants, and translocated to all parts of plant. When the insects feed on such plants, they are killed. These are actually the stomach poisons. These are best against sucking insect pests.

4. **Fumigants**

These insecticides are mostly in the form of vapors & in the form of solids which give fumes into the air with the ordinary temperature. These enter the body of the insect by inhaling through spiracles. Examples: Aluminum phosphide (Celphos, detia, delicia, postoxin), methyl-bromide, EDCT (Ethylene dichloride carbon tetrachloride).

II. MODE OF ACTION

1. **Physical Insecticides**

Those insecticides which insect pests through their physical action.

2. **Protoplasmic Insecticides**

Those insecticides which kill the insect through their action on the protoplasm of cells.

3. **Respiratory insecticides**

Thse are those insecticides which kill the insects by checking the respiration of insects.

4. **Nerve Poisons** Axonic Poison

These are those insecticides which kill the insects by their action on nervous system of insects.

5. **Miscellaneous Insecticides**

a) Insect Attractants:e.g., Methyl eugenol, gyplure, hexaplure etc.

b) Insect Repellents: e.g., creosote, mercurous chloride, tricholorobenzene etc.

III. MODE OF CHEMICAL NATURE

According to the chemical nature, insecticides are divided into two main groups:

1. **Inorganic Insecticides**

Some of the first insecticide ever used are in this category such as arsenics, sulphur, Paris green, sodium floride etc.

2. **Organic Insecticides**

i) **Natural organics**

A) **Animal Origin:**

Oils: fish oil. Oils used as insecticides are of two types:

Summer spray Oils: These are sprayed in spring when buds of plant are sprouted.

Dormant Spray Oils: These are sprayed in winter when buds are dormant. Also called winter oils.

Mode of Action of Oils: Oils action is of physical nature. Spiracles of insects are filled by oils and blockage of air inhalation cause suffocation which results in the death of insects.

B) **Plant Origin:** e.g., Rotenone, Nicotine, Ryania, Derris, Pyrethrum etc.

(b) **Synthesized Organics**

(c) **Organochlorine Insecticides** (Chlorinated hydracarbons):

Salient Characteristics: This is group of synthetic chemicals. These take a long time to disappear from environment and accumualte slowly in the bodies of insect.

Mode of Action: It unstabilize the peripheral nervous system. Ultimatley there is hypertoxicity, paralysis and finally death of the insects.

Antidotes: If sudden poisoning occurs in human being, then following antidotes of these chemicals such as atropine sulfate, raw egg and milk etc. can be used.

Range of Target Pest Insects: These insecticides are effective against a variety of insects especially beetles, weevils, mosquitoes house flies, lice, fleas etc.

Examples:

DDT, Toxaphene, BHC, Aldrin, Dieldrin, Chlordane, Heptachlor, and Endrin.

b) Organophosphorus Insecticides

Salient characteristicsL They are not as persistent as chlorinated hydrocarbons. It may be contact, stomach or fumigants in action. These insectides dor not accumulate in fat bodies of animals.

Mode of Action:

These insecticides inhibit the production of cholinestrase enzyme which removes acetylcholine (liquid) from the synapse, due to an impulse will go on passing and disturb the insect continuously. Finally death of insect occurs.

Toxicity: It varies in toxicity from extremely hazardous to slightly hazardous chemicals.

Antidotes: Same as in case of chlorinated hydrocarbons.

Range of Target Pest insects: These are applicable for may insects e.g, sucking insect pests of cotton. Bollworms, squash bug, aphids etc.

Examples:

Acephate (Orthene), Azinphos methly (Gusathion.M), Cartap (Padan), Diazinon (Basudin), Dicrotophos (Bidrin, Carbicron), Dichlorvos (Nogos, DDVP, Vapona), Fenthion (Lebaycid), fenitrothion (Sumithion), Formothion (Anthio), Malathionn, Mevinphos (Phosdrin), MICP (Mipcin), parathion Methyl (Folidol M), Phosphamidon (dimecron), Phorate

inco-Necotinide
Biopesticides
Microbial insecticides
Chloropyrifos

(Thimet), Primiphos methyl (Actellic), Triazophos (hostathion; Trichlorfon (Dipterex), Dimethoate (Cygon, perfekthion, Rogor), Disulfoton (Disyston) Monocroptophos (Azodrin, Nuvacron), Oxydemeton Methyl (Metasystox,). Phosmet (Imidan

c) Carbamates

Salient Characteristics: It is the new group of synthetic insecticides.

Mode of Action: These are similar to the organophosphates in properties and action.

Antidotes: Same as in chlorinated hydrocarbons.

Range of Target Pest Insects: These are more effective than previous, for insect pests of different crops.

Examples: Carbofuran, Carbosulfan

Aldicarb (Temik), Carbaryl (Sevin), Carbaryl plus Gamma BHC (Sevidol), Carbofuran (Furadan) Methomyl (Lannate) etc.

d) Synthetic Pyrethroids

Salient Characteristics: These have low toxicity to man and other vertebrate animals.

Mode of Action: Same as in organophosphates.

Antidotes: Same as in Organochlorines.

Range of Target Pest Insects: These have a wide range of its effectiveness including insect pests of cotton, wheat and other field crops.

Examples:

Cypermethrin (Ripcord, Cymbush, Sherpa, Arrivo), Cyermethrin plus profenofos (Polytrin-C), Permethrin (Ambush) Decamethrin (Decis), Fenvalevate (Sumicidin), Nurelle. Danitol and Mavrik.

B. RODENTICIDES

These chemicals disturb the vital processes of rodents (rats, shrews, squirrels etc,) by chemical action.

Examples:

Brodifacoum (Klerat), Coumatralyl (Racumin), Sodium

(Thimet), Primiphos methyl (Actellic), Triazophos (hostathion, Trichlorfon (Dipterex), Dimethoate (Cygon, perfekthion, Rogor), Disulfoton (Disyston) Monocroptophos (Azodrin, Nûvacron), Oxydemeton Methyl (Metasystox,). Phosmet (Imidan

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Examples:

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C. **ACARICIDES**

This group of chemicals is used to control the mites and ticks etc.

Examples:

Chlorobenzilate (Akar), Dicofol (Kelthane), Ethion, Propergite (omite), Tetradifon (tedion).

VIII. **INTEGRATED CONTROL**

It is also called pest managemnet or intergrated pest management or I.P.M. "It is the control of insect pests by an combinations of control methods which result in less hazards to man and his environment." In the beginning, insect pests were controlled by parasites, predators i.e, by biological control methods, and whenever and wherever insects were not controlled by parasites and predators, the chemical control was applied to control the pest at that place. Now a days, generally many methods of control are combined to control a particular pest to a particular crop.

Elemntnts of Integraed Control

1. Cultural control
2. Physical control
3. Mechanical control
4. Biological control
5. Legal control
6. Reproductive control
7. Chemical control
8. Pheromonal control

Harmonses: The secretions which are produced organisms into their blood, and they act at a place different from their place of origin are called harmones.

Pheromones: the secretions which are thrown outside body are called pheomones.