UNIT 7 ECOLOGY AND QUANTITATIVE ESTIMATION OF PESTS

Structure

7.1 INTRODUCTION

In the previous units you have learnt about the different kinds of pests, their nature of damage and extent of losses caused by them. In this unit you will study ecological concepts such as ecosystem, food chain, biotic potential, environmental resistance and balance of nature. You will also learn about the methods of crop loss assessment due to pests. This unit explores some fundamentals of pest ecology in relation to natural and agroecosystem and how an understanding of these fundamentals can enhance pest management with minimal disruption of ecosystem processes. The methods of assessing pest populations given in the Unit are those that are widely used in pest management programmes.

Objectives

After studying this unit, you should be able to:

- define the ecology of pests,

- describe an agro-ecosystem,
- differentiate between a natural and an agro-ecosystem,
- explain food chains and food webs,
- describe types of population growth in organisms,
- explain balance of nature,
- describe different sampling methods,
- define population dynamics of organisms,
- explain methods of quantitative estimation of pests and
- describe methods of crop loss assessment.

7.2 ECOLOGY AND ITS BRANCHES

The term ecology is derived from Greek word '*Oikos*' meaning home and '*logos*' meaning study. The study of home of organisms is thus referred to as ecology.

Ecology is also called the study of home of organisms.

The place where the organism lives is called **habitat**. It is the place where one will go to search for the organism. For example, the habitat of rice stem borer is the rice field. The habitat of an organism is comparable to the address of a human being.

A species of pest shares its habitat with plants, other pest species, predators, parasites and pathogens (natural enemies). Crop plants provide food and shelter to the pests. Weeds in the field act as alternate food source in the absence of crop plant. Individuals of the same pest species compete with each other for food, space and mates when these are scarce. Organisms of different species of pests compete for food and space. Natural enemies feed on pests and try to keep their populations under check. There is also competition among different species of natural enemies for food and space. Above all, different organisms are affected by meteorological or physical factors such as temperature, rainfall, humidity, wind speed, sunshine hours *etc*. All aforesaid components thus form integral part of the ecology of any pest species.

Habitat of an organism is like address of a human being.

The **Ecology** can thus be defined as the **study of interrelations between the organisms on one hand and their physical environment on the other**. For example the ecology of rice stem borer would encompass rice plant, weeds in rice field, other species of pests infesting rice, its natural enemies such spiders, coccinellids and other beetles, parasites and pathogens and physical factors of the environment.

Branches of Ecology

Ecology can be classified into two branches: autecology and synecology.

i) **Autecology** is the study of relations of individual pest species to their habitat.
ii) **Synecology** is the study of interrelations of all the species of organisms together in a particular habitat. It is also called as the ecology of biotic community.

SAQ 1

i) What is meant by ecology?

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ii) What is synecology?

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iii) What is a habitat?

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7.3 LEVELS OF ORGANIZATION – INDIVIDUAL TO BIOSPHERE

In the environment living organisms can be arranged in the following six hierarchical (from lowest to highest) levels of organization.

Individuals

Individual organisms are fundamental units of any living system. Exchange of genetic material i.e. reproduction and hence multiplication takes place at the level of organisms. The adaptation of the species to the environment thus occurs at individual organism level.

Population

Population is also defined as assemblage of potentially inter-breeding individuals.

All the individuals of a pest species in a habitat at a particular time constitute a population. For example, the individuals of rice stem borer in a rice field would be called a population. Likewise, all the individual of a spider species in a rice field would constitute a population. Individuals of a pest species may compete for food, space or mating with one another. The competition among the individuals of a pest species is called **intraspecific competition.**

Biotic community

Assemblage of all the populations of organisms in a habitat is called biotic community. For example, the biotic community in a rice field would include rice pant population, population of weeds, populations of all the pests like stem borer, brown plant hopper, stink bug, etc. populations of natural enemies such as spiders, coccinellids, populations of parasites and pathogens and populations of other organisms. The individuals of a pest species may compete with each other (intraspecific competition) and they also compete with individuals of other species. The competition among the individuals of different species is called **interspecific competition.**

Ecosystem

The system generated due to continuous interaction of biotic community with physical factors of environment such as temperature, humidity, sunshine, soil and wind, etc. is called an ecosystem. Ecosystem is called the basic unit of environment as it contains both biotic and physical factors of the environment. Ecosystem may thus be defined as self-sufficient habitat where continuous interaction of biotic community with physical environment leads to well defined trophic structure, continuous flow of energy through the community and cycling of materials between living and physical components.

Biome

Similar types of ecosystems together are known as biome. For example all tropical forests on land will constitute a tropical forest biome and temperate deciduous forests will be called temperate forest or grassland ecosystems will make a grassland biome.

Biosphere

All habitable space on and around the earth where life can exist is collectively known as biosphere. Biosphere can also be defined as aggregation of all the biomes.

SAQ 2

i) What is a population?

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ii) What is meant by 'biotic community'?

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iii) Define biome. Give one example.

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7.4 ENERGY FLOW IN ECOSYSTEM

Flow of energy in ecosystem is unidirectional. It cannot be cycled.

Flow of energy from one organism to another in the biotic community is called food chain. In this process an organism feeds on another organism and in turn is fed upon by another. For example, insect pests feed on plants, parasites/predators feed on pests and the hyperparasites on parasites. Some common food chains are as follows (Fig. 7.1)

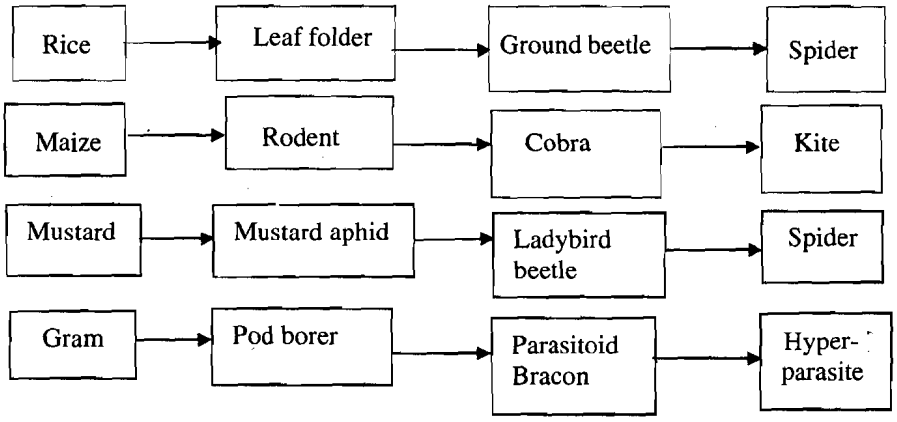

Fig.7.1: Common food chains in rice, maize, mustard and gram crops.

Man acts as herbivore as well as carnivore.

The food chain is thus also called linear feeding sequence in the community. Animals in biotic community directly or indirectly depend upon plants for their food. Plants in turn manufacture their food in the presence of sunlight through photosynthesis. Sun is thus the ultimate source of energy for all life on earth.

Plants are called *autotrophs* (or *producers*) because they can manufacture their food themselves. All other organisms (mainly animals) in the biotic community are called *heterotrophs* (or *consumers*). Heterotrophs cannot manufacture their food and thus depend for their food on other organisms. Heterotrophs are both herbivores (phytophagous) as well as carnivores. Herbivores are animals, which feed on plants. Examples of herbivorous organisms are: insect crop pests, phytophagous mites, higher animals such as cow, goat, sheep, rabbit; birds like parrot *etc.* Carnivores are animals, which feed on other animals.

Carnivores can be primary, secondary, tertiary or quaternary. *Primary carnivores* are those organisms, which feed on herbivores. *Secondary carnivores* feed on primary carnivore, tertiary on secondary and quarternary on tertiary and so on. Examples of primary carnivores are predators and parasites of insect pests. These are useful organisms as they try to control harmful organisms. Secondary carnivores feed on primary carnivores. These are called hyperparasites as they are parasites on parasites. **From pest management point of view secondary carnivores are harmful as they kill useful carnivores.** In this way tertiary carnivores will be useful as they reduce secondary carnivores that harm useful predators and parasites. Some organisms can function both as herbivore and carnivore such as crow. These are called **omnivores** (*omni*: all). Man can feed on plants as well as other animals.

7.4.1 Trophic Levels

In an ecosystem thus there is a definite trophic structure. Feeding positions of different type of organisms in a community are called trophic levels. Trophic level denotes the number of steps a species is away from sun, which is ultimate source of energy. The plants (autotrophs) thus belong to *first trophic level* as they directly utilize sun's energy to manufacture their food (Fig. 7.2). Herbivores are placed at *second trophic level*, primary carnivore at *third*, secondary carnivore at *fourth*, tertiary carnivore

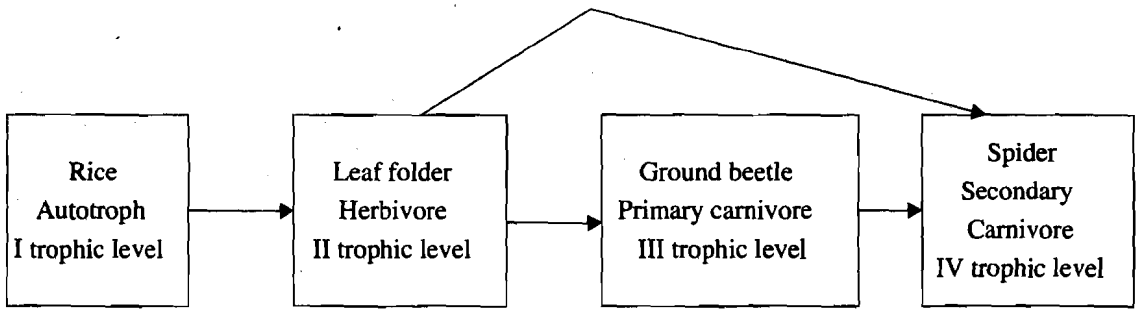

Fig. 7.2: Trophic levels in a food chain.

at *fifth* and quaternary carnivores at *sixth trophic level*. Some organisms can occupy more than one trophic level in the food chain. Man being omnivorous functions at second trophic level as herbivore and at third trophic level as carnivore. Similarly in rice ecosystem spider can function at third trophic level as predator feeding on insect pest. It can also occur at fourth trophic level when it feeds on useful insects like dragon flies.

7.4.2 Niche

Niche of an organism is like the profession of a human being in society.

Functional role of an organism in the community is termed as ecological niche. In other words, it implies whether an organism is producer, herbivore or carnivore. The ecological niche is similar to the profession of a human being.

A parasite that uses another parasite as its host is called as hyperparasite.

Only 1-2% of sun's incident radiation is utilized by plants in photosynthesis. Then at each trophic level 90 % energy gets dissipated and only 10% is passed on to succeeding trophic level. Thus availability of energy decreases as it moves along the food chain. This leads to simultaneous reduction in biomass of organisms at different trophic levels. Therefore, biomass of plants (autotrophs) is maximum in the community. Among heterotrophs the insect pests are most abundant and predator and parasites are comparatively very low. The hyperparasite populations are very-very low.

There is unidirectional flow of energy in the ecosystem. Energy flows from sun to autotrophs and then to heterotrophs but it cannot be cycled back. However it can be stored. For example the agricultural produce can be stored and then used for consumption. There is cycling of materials between living and non-living components

of the ecosystem. Plants absorb nutrients from soil and grow. The dry parts of plants such as leaves, branches or stubbles get incorporated into the soil. These are then decomposed by microorganisms and release nutrients. Similarly dead bodies of heterotrophs get decomposed and release minerals into the soil. In this way cycling of materials takes place.

7.4.3 Types of Food Chains

The food chains can be broadly classified into:

i) Grazing food chain and
ii) Detritus food chain.

Presence of food web results in stability of an ecosystem.

i) **Grazing food chain**: Grazing food chain starts from green plants (producers) and moves on to herbivores and different categories of carnivores as depicted above.
ii) **Detritus food chain:** Detritus food chain starts from dead organic matter and moves on to detrivores and then to predators. Detrivores are microorganisms such as bacteria and fungi, which feed on dead plant and animal matter. The detrivores are then fed upon by predators.

The grazing and detritus food chains do not function in isolation but are interconnected in any ecosystem. However the proportion of energy flowing along two food chains varies from ecosystem to ecosystem. In grassland where animals graze most of the energy moves in grazing food chain. In agroecosystem also, most of production is harvested by man from the grazing food chain and very less proportion of energy is allowed to move in detritus pathway. On the other hand bulk of the energy is transferred in detritus food chain and very less energy moves in grazing manner.

7.4.4 Food Web

Interlinking of food chains is called food web. Food web can also be described as complex food chain. This happens when one producer is fed upon by many herbivores. Similarly many predators may consume one herbivore or one predator may consume many herbivores. The example of a food web in a rice ecosystem in given in Fig. 7.3. Interlinking of food chains provides alternate food sources to the organisms. If one food source is missing then organism can derive energy from other food source. But this does not happen in case of simple *food chain, where only one source of food is available to the organism.* In the absence of this food source, the population of the organism would perish. Food web thus ensures stability of biotic community in the ecosystem. Generally in tropical climate we encounter complex food chains. In temperate climate food chains are very simple. Simplest type of food chain is found in Tundra. These consist of moss, reindeer and man or moss, rodents and snow fowl. In such cases, if one link in the food chain misses then population at succeeding trophic level is found to suffer because alternate food source does not exist.

In agro-ecosystems the food chains are less complex than in natural ecosystems like forests. In agriculture we adopt clean cultivation through weeding and thus alternate sources of food are removed from the ecosystem. The agro-ecosystems are thus very prone to pest epidemics.

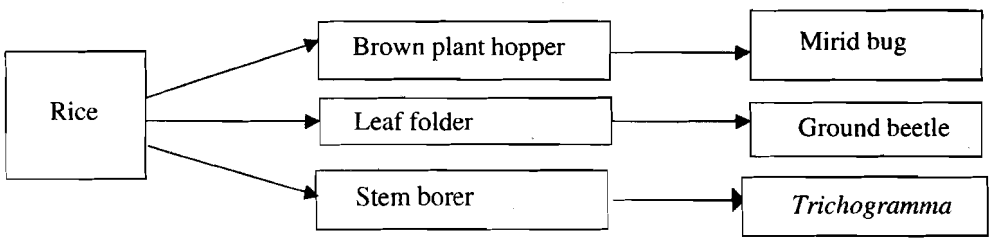

Fig. 7.3: Food web in rice ecosystem.

Ecological succession is also known as ecosystem development (eco-development).

7.4.5 Ecological Succession

We generally believe that only physical factors influence the living organisms and reverse does not happen. However it is not true. Living organisms i.e. plants, animals and living organisms are not slave to the physical factors. These continuously tend to modify the chemical nature of water, soil and air that composes the physical environment and make it more suitable for life. Ecological succession or ecosystem development is very good example in this regard.

The systematic and predictable change in the biotic communities in a habitat is called **ecological succession** or **ecosystem development**. There may be primary succession or secondary succession.

Primary succession takes place where no biotic community existed earlier. For example, on a sand dune or hard rock, plant like lichens and moss appear first of all. These modify the soil conditions and make it more suitable for life and then grasses appear. Grasses are then succeeded by shrubs, small trees and big trees. The changes in plant community also leads to simultaneous changes in animal communities. The community, which appears in the beginning of succession, is called **pioneer community**. The organisms in this community are small in size, very hardy and can tolerate harsh conditions of the environment. The community, which appears at the end of succession, is called **climax community**. The organisms in the climax community are large and are better competitors. Different communities during succession are called **seral stages** or **seres.**

Secondary succession occurs when biotic community in a habitat is destroyed by natural calamities like fire, floods or landslides. In agricultural field (agroecosystem) the succession starts with ploughing of soil and sowing of the crop. The succession in agroecosystem never reaches climax stage. We terminate it by harvesting the crop.

SAQ 3

i) What is food chain?

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ii) What is meant by food web?

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iii) What is a trophic level?

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iv) What do you understand by the term primary consumer?

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v) In what way are tertiary consumers harmful to us?

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vi) What are seral stages?

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vii) What is a primary succession?

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7.5 TYPES OF ECOSYSTEMS

Ecosystems can be broadly classified as terrestrial ecosystems and aquatic ecosystems. **Terrestrial ecosystems** exist on land. These can be further categorized into grassland ecosystem, forest ecosystem and agro ecosystem etc. based on vegetation type. **Aquatic ecosystems** exist in water. These can be classified into fresh water (river) ecosystem, marine (sea) ecosystem or estuarine ecosystem. Estuaries are formed where river merges into the sea.

In agro-ecosystem, succession does not reach climax stage. It terminates at harvesting.

7.5.1 Aquatic Ecosystem

Aquatic ecosystems can be a pond, lake, river or ocean. Abiotic substances include basic inorganic and organic compounds such as water, carbon dioxide, oxygen, soil, calcium, nitrogen, sulphur, phosphorus, amino acids and others. A small portion of vital nutrients is in solution and immediately available to the organisms. But a large portion is held in reserve in non-living matter as well as in organisms themselves. The various biotic components of an aquatic ecosystem are as follows:

a) Autotrophs

Producer organisms or autotrophs in pond ecosystem can be of two main types:

i) Macrophytes: These are rooted or large floating plants. These grow in shallow water only.
ii) Phytoplankton: These are minute floating plants usually algae, distributed throughout the water as deep as light penetrates. In abundance, the phytoplankton gives the water a greenish colour, otherwise these producers are not visible to the casual observer. In deep ponds, lakes and oceans, phytoplankton is more important than rooted vegetation in the production of basic food for the ecosystem.

b) Heterotrophs

Herbivores or primary consumers in aquatic ecosystem can be categorized into two types:

Organisms feeding on dead organic matter are called detrivores.

i) Zooplankton: These are the animals, which float in water.
ii) Benthos: These organisms live at the bottom of the water bodies.

These two animal forms (heterotrophs) correspond to the two autotrophic forms i.e. phytoplankton and macrophytes. These are also called **macroconsumers** as they are higher animals. Another important consumers are the microorganisms, which are called **microconsumers** or **detrivores**. These feed on dead organic matter. These along with herbivores are fed upon by secondary consumers or primary carnivores such as predacious insects or fish. Smaller fish is eaten by large fish and large fish is consumed by still larger fish and food chain goes on to tertiary and quaternary levels.

7.5.2 Forest Ecosystem

Evergreen forests also shed their leaves but not at a time unlike deciduous forests.

Forest ecosystem comprises a variety of trees with differing growth forms and a number of shrubs and herbs. The uppermost level of forest is termed as **canopy**. It is fully exposed to sunlight and winds. Trees extend from a height of about 3 metres to 25-30 metres the forests of the world, can be distinguished in to major biomes such as **tropical forests, temperate forests** and **coniferous forests** etc.

Only 1 % of incident radiation is utilized by plants for photo-synthesis.

Tropical forests occur in India, Malaysia, North Australia and parts of South America. These are classified into **tropical rain forests** and **tropical seasonal forests.** Tropical rain forests exist where rainfall is heavy and distributed throughout the year. On the other hand tropical seasonal forests are found in areas with a dry season when leaves are shed.

Temperate forests are colder than tropical forests. Temperate deciduous forests are found in North America, Europe, Eastern Asia, Chile etc. Tallest trees of the world such as Eucalyptus of Australia attaining a height of more than 100 metres occur in these forests.

Coniferous forests are found in northern areas of North America and Eurasia between the tundra and the temperate deciduous forests. These exist in a very cold climate with heavy rainfall. In these areas, the summers are very short and winters are longer.

7.5.3 Agroecosystem

In agroecosystem we experience high pest population due to human interference.

Agroecosystem is short name for agricultural systems. Agroecosystems are characterized by active manipulation by man for attaining more and more production.

Agroecosystems (cultivated fields) differ from natural ecosystems (such as forest, grassland or lake) in the sense that many natural occurring processes are augmented or replaced/ substituted completely by man-mediated processes. Agroecosystems can be distinguished from natural ecosystem on the following counts:

- In natural ecosystem there is **natural dispersal of seeds** from plants. The new plants get established wherever the seeds fall. In agroecosystem, the natural seed dispersal is replaced by manual or mechanical sowing of the seed. Man ploughs the land with bullocks or tractor and then sows the seed.
- In natural ecosystem, **plants get nutrients from natural cycling of minerals.** The leaves of plants, dead bodies of herbivores and carnivores get decomposed and release nutrients, which are then absorbed by plants. In agroecosystem, farmers apply farmyard manure and inorganic fertilizers such as nitrogen, phosphorus and potassium, which augments natural mineral cycles.
- In natural ecosystem a **large number of plants occur together** thus natural ecosystems are more diverse. Through competition, the weaker species get eliminated. In agroecosystem, all plants (weeds) except crop plants are removed and thus it is very simple community.
- In agroecosystem the **soil is ploughed** and prepared for sowing of the seed. This augments natural soil building processes. However this also leads to **soil erosion.**
- The natural ecosystem, due to plant diversity, harbours many carnivore species. These **natural enemies keep the populations of pests under check.** In agroecosystems due to simple community, **natural enemy fauna is scarce.** In the absence of natural enemies pests attain very high population. Therefore pesticides or other control measures have to be adopted.
- In agroecosystem **high yielding varieties** are grown with more amount of fertilizers and irrigation for getting higher production. These are protected from pests through application of pesticides. Crop varieties with inherent resistance to insects and diseases are also bred through genetic selection. The genetic selection thus replaces the selection process, which earlier used to occur in nature.

The agroecosystems due to their very simple community structure are prone to pest outbreaks/epidemics. These therefore need to be managed in an ecological sound manner.

Life Systems: The "life system" concept was initially conceived by Clark et al. (1967) to reinforce the idea that a population cannot be considered apart from the ecosystem with which it interacts. The life system consists of the pest population plus its "effective environment". Every insect (or other) population is surrounded by environmental factors that may impact it positively or negatively. The effective environment thus includes food supply, predators, pathogens, competitors, hiding places-in short, anything that may enhance or limit survival, reproduction, and/or dispersal of a pest species.

SAQ 4

i) What is a phytoplankton?

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ii) What do you understand by the term benthos?

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iii) What type of vegetation is observed in forest ecosystem?

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iv) Define an agroecosystem.

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7.6 POPULATION GROWTH

Population of an organism grows is two ways:

i) Birth of new individuals and
ii) Immigration of individuals from other areas.

Organisms showing J-shaped population growth are also called opportunists.

Population of an organism declines due to:

i) Death of individuals and
ii) Emigration of individuals to other areas. Population size of an organism is thus the result of forces of reproduction and forces of annihilation.

7.6.1 Types of Growth

Populations have two patterns of growth

A) J-shaped growth form
B) S-shaped or sigmoid growth form

A) J- shaped growth

In J-shaped growth, population density increases rapidly in an exponential form. In the beginning the population does not experience any environmental resistance (Fig. 7.4). Population growth stops abruptly and it crashes when environmental resistance intervenes. Environmental resistance appears because either i) food or space becomes limiting or ii) some physical factors like frost or any other factor intervenes or iii) reproductive season suddenly terminates. This type of growth occurs when ecosystems have low diversity, for example, agroecosystems. In this case density independent factors control the population. Most pest populations exhibit this type of growth. **These species are called opportunistic species.** In the absence of competition, they exploit the habitat and assume very high populations.

B) S-shaped growth

In S-shaped growth, the population increases slowly at first, then it grows rapidly but slows down again gradually (Fig.7.4). In this type of growth, the environmental resistance starts intervening from beginning itself. The maximum upper limit of the population which can be achieved is called the carrying capacity. This type of growth is achieved when density dependent factors control the population. This type of growth is attained in high diversity ecosystems such as forests and orchards.

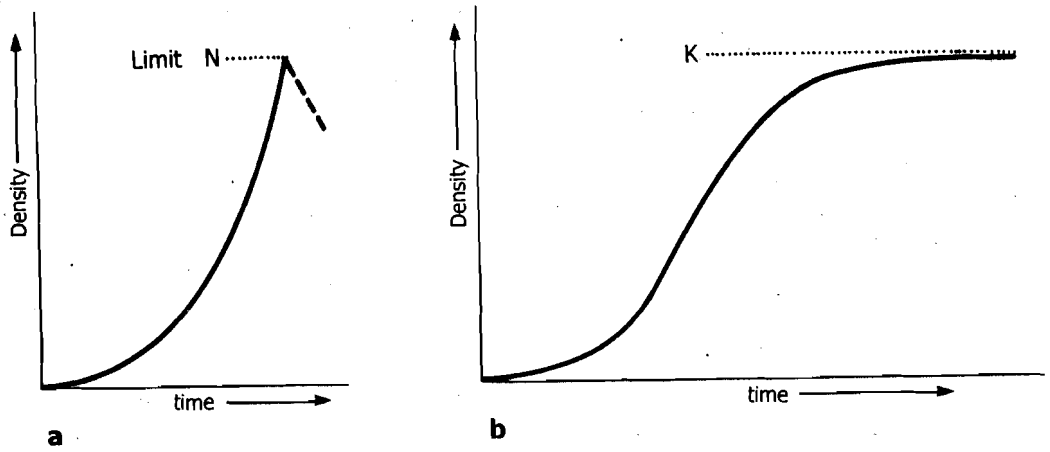

Fig. 7.4: Population growth curves. a) J- shaped curve, b) S-shaped curve.

7.6.2 Biotic Potential

Biotic potential is also known as intrinsic rate of natural increase.

Inherent capacity of an organism **to reproduce, survive and multiply** is called biotic potential. This is also called intrinsic rate of natural increase of a species. This is the maximum rate of increase of a species under unlimited environmental conditions. Unlimited environment means that a species does not experience shortage of any resources. The biotic potential is constant for a species. In reality, species always encounter some sort of resource constraints. The biotic potential is thus never realized in nature. The multiplication that occurs in nature is thus realized potential and not biotic potential. For example, potential number of eggs of a species several folds higher than the actual number of eggs that are laid. The following example illustrates magnitude of population of a pest species if it could realize its biotic potential.

Spotted bollworm of cotton *Earias fabia* is a very serious pest of cotton. A female lays 300 eggs and completes life cycle in 1 month. Under favourable conditions 12 generations can be completed in a year.

Therefore, we see that insects are very prolific breeders. The progeny of a single female after completion of one year will be in trillions. Moreover, there are lakhs of insect species and each species has millions of females. If all species realize their biotic potential then, there will no place in this world for human beings to live in. However, this never happens because forces of annihilation i. e. environmental resistance are functioning simultaneously. They ensure that balance of nature is maintained unless man interferes.

Environmental resistance consists of both biotic and abiotic mortality factors.

Biotic potential can be divided into: A. Reproductive potential and B. Survival potential

A) Reproductive potential

It is the inherent capacity of the organisms to reproduce. It depends upon the fecundity of females.

B) Survival potential

It is the capacity of an organism to survive in nature. Survival potential can be further subdivided into:

i) Nutritive potential and
ii) Protective potential

i) Nutritive potential

It is the capacity of the organisms to utilize environmental resources as food for their survival.

- A few of the organisms only ***feed on a specific species*** of host plant. These are called monophagous pests. Mulberry silkworm, *Bombyx mori* and yellow rice stem borer, *Scirpophaga incertulas* are examples of **monophagous** insects.
- Some organisms ***devour a few related species*** of host plants. Such pests are termed as **oligophagous**. The cabbage butterfly, *Pieris brassicae* and diamond back moth, *Plutella xylostella* feeding on cole crops are included among oligophagous insects.
- Some organisms can ***utilize a large number of host plants*** as their food. These organisms are called **polyphagous**. For example, locust, grasshoppers, gram pod borer, cutworms, armyworms etc.

In the absence of one host plant, the oligophagous or polyphagous organisms can survive on other plants while monophagous pests will perish in such a situation. The polyphagous organisms thus are better adapted for survival than oligophagous organisms, which in turn are better adapted than monophagous ones.

ii) Protective potential

It is the capacity of organisms to protect themselves from vagaries of nature. The organisms have to defend themselves from adverse weather conditions as well from their natural enemies.

7.6.3 Environmental Resistance

It is the sum total of all the factors, which tend to annihilate or kill population of organisms in nature. The mortality factors can be categorized as

A. Physical or abiotic factors
B. Biotic factors.

A) Physical or abiotic factors

Physical factors such as temperature, humidity, rainfall, sunlight, space etc. always function in density independent manner. The intensity of their action is not related to the population density of organisms on which they act. The mortality may be very

heavy at low population or it may be very low at high population density. Therefore these are called density independent mortality factors or catastrophic factors.

B) Biotic factors

Biotic mortality factors can act in density dependent or density independent manner.

Biotic mortality factors such as natural enemies (parasitoids, predators and pathogens) may act in density dependent or density independent manner. In density dependent mortality factors, the intensity of mortality increases with increase in the population of the organisms on which they act and it decreases as the population of organism decreases. A natural enemy functioning in a density dependent manner is useful for biological control of organisms. Density dependent factors regulate the population density of the subject organisms. Regulation of density means that they neither allow the density to reach very high level nor allow it to become extinct. Natural enemies through regulation also ensure their own survival. Because in the absence of food their population will also perish.

7.6.4 Interaction between Biotic Potential and Environmental Resistance

Foreign pests gain entry into new areas due to quarantine negligence.

Interaction between biotic potential and environmental resistance ensures balance of nature in the following manners:

- **Organisms possessing high biotic potential face more environmental resistance in nature.** Most of pest populations possess high biotic potential. In this way overpopulation or pest outbreaks are avoided. However in agro-ecosystems due to cultural practices and pesticide application, the populations of natural enemies are adversely affected. This reduces the environmental resistance for the pest populations and thus pest epidemics are experienced.
- **Organisms possessing low biotic potential, encounter less environmental resistance in nature.** This ensures that species of organisms do not face extinction. Most of the higher animals and birds possess low biotic potential but they ensure the survival of the progeny through parental care. However, due to human interventions when environmental resistance for such species is increased then they become extinct. Many wild life and animal species are facing extinction due to hunting/ poaching activities of man.
- **A pest species introduced accidentally into a new area attains very high population there.** When a pest species gains entry into new country due to quarantine negligence then it leaves behind its natural enemy fauna. It thus faces less environmental resistance in new area and thus proliferates. The pest getting entry into new countries is called **exotic** or **foreign pests.** For example, potato tuber moth, *Phthorimaea operculella;* diamond back moth, *Plutella xylostella;* apple wooly aphid, *Eriosoma lanigerum;* golden cyst nematode etc. are some of the examples of foreign pests introduced in India.

SAQ 5

i) Name the two population growth forms.

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ii) What is reproductive potential?

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iii) Explain nutritive potential.

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iv) What are biotic mortality factors?

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v) What are exotic pests?

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7.7 POPULATION ESTIMATES: QUANTITATIVE BASIS OF PEST MANAGEMENT

A collection of sample units is called a sample.

Estimation of pest population is required to

1. determine whether pest population has reached economic levels
2. evaluate effectiveness of control measures
3. evaluate effectiveness of host plant resistance
4. study population dynamics

Populations are estimated through sampling the habitat of the pest. Sampling is necessary because it is impossible to count each and every individual of the pest in the habitat. Therefore, pest population is counted on selected plants or plant parts such as leaf, stem or inflorescence or in crop plots. Therefore, these units *viz.* plant, plant part or plot on which pest population is recorded is called **sample unit**. The pest population has to be recorded on several randomly selected sample units in the habitat. The number of sample units used to estimate pest population constitutes a **sample**. These sample units are called random because each unit is given equal chance of inclusion in the sample. We should not show any bias in the selection of these units. This can be ensured by adopting statistical techniques such as use of random numbers in the selection of sample units. The mean population density is then worked by averaging the population of all sample units. This sample estimate is taken as the representative of actual pest population in the field.

Types of population estimates

The population estimates are of three types.

A. Absolute estimates
B. Relative estimates and
C. Population indices

7.7.1 Absolute Estimates

Absolute estimates represent pest population in terms of **number of pests per unit area**. These are obtained from three areas: vegetation, air and soil.

Berlese funnel is used to separate pests from soil and other materials in the sample.

i) *Absolute estimates from vegetation:* The direct approach is to sample all plant matter over a unit area of soil surface. The alternate approach is to use a plant or a plant part such as a branch or leaf as the sample unit. We should then also know the number of sample units per unit area. The absolute population can then be estimated by multiplying pest population per sample unit by the number of sample units per unit land area. For example, number of aphids per unit area in field of wheat is estimated by the product of aphid population per tiller and number of tillers per unit area.

ii) *Absolute estimates from air:* Suction traps and rotary traps are two basic methods used for this purpose. These suction traps are of fixed type. They usually consist of a metal gauze cone into which the air is sucked by an electric fan. The catch in these traps is exclusively insects so there is problem of counting the number per

sample. These catches are in terms of insect per hour and these should be converted into aerial density.

ii) *Absolute estimates from soil:* The soil pests are sampled by digging up a unit area to a predetermined depth. If the insect being sampled is small and abundant and deep in the soil then core sampler is the best device. If the insect is large or less dense and present in the litter or 1 cm topsoil, the sample unit of large area should be taken. Often a square meter of litter plus top 1 cm of soil is a reasonable sample unit. Pests are then separated from the soil by dry methods such as Berlese funnel (Fig. 7.5). This funnel is warmed by an electric bulb and pests move to the collecting tube at the bottom of the funnel.

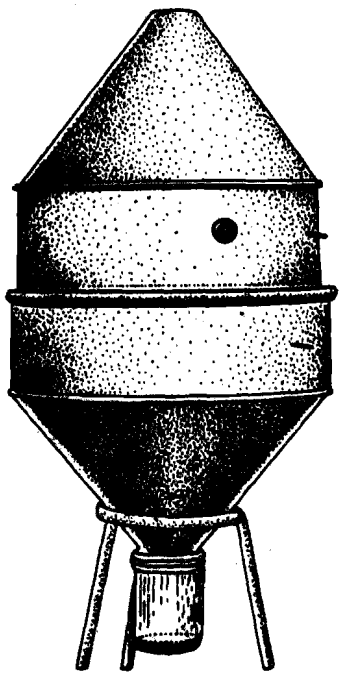

Fig. 7.5: Berlese funnel

7.7.2 Relative Estimates

Relative estimates represent some fraction of actual pest population present in the habitat. These estimates are useful in studying fluctuations in a population over time in a habitat. The absolute methods are very labour intensive but relative methods are cheaper and provide sufficient information with regard to effectiveness of control measures and comparison of population overtime and space. Pest monitoring is a process by which the numbers, and life stages of pest organisms present in a location are established. The process of pest monitoring is often referred to as **scouting**. Some specific monitoring devices and techniques are discussed below:

i) *Visual counting on plants:* Individual pests are counted on leaves, stems and fruits. For example: Plant parts may also be cut open to count stem, borer larvae per stem fly larvae per fruit, or weevil larvae per tuber. Pests inside plants such as midge larvae in sorghum, lepidopterous larvae in stems or beetle in stored grains may be detected by X-rays. An insecticidal knock down spray can also be used to dislodge insects from the plants. For example, sorghum heads placed in a box and treated with such insecticides flush out bugs and thrips, which are then counted. Small insects may be brushed off by hand or machine or scraped from the plants as with white scale insects on sugarcane. Aphids may be put in water and then estimated based on their population in per unit water volume. Plants or their parts can be enclosed within a container and a suction sampler is used to collect all the pests from them. In relative methods there is no need to know the number of sample units per unit area unlike absolute methods. So a lot of saving in sampling is achieved.

Monitoring or 'walking the field' is the essential step in IPM.

ii) *Water traps*: Water traps are shallow, water-filled plastic or metal trays. Some times these are painted with a particular colour like yellow or pheromone or some attractant is incorporated. The traps must be protected from the weather. The catch should be regularly removed and trap filled regularly. Water traps are more effective if raised above ground level, but height will depend on the species being sampled and the time of the year. Vertical baffles placed in the trap can increase the catch. Yellow water traps have been used to sample aphids. In India, water traps have been used in conjunction with fish meal bait to attract sorghum shoot flies. (Fig. 7.6)

Sweep net is used for obtaining relative population estimate.

.iii) *Sweep net:* The sweep net is used for general population assessment. If diameter of net, no of sweeps and technique can be standardized then consistent results can be obtained from sample to sample. The catch is expressed as the average number of pests per sweep. **Ground cloth**: The ground cloth is most widely used method in row crops such as soybeans and sorghum. It is also adequate for sampling the fauna of bushy weeds. This method consists of spreading a piece of thick cloth on the ground under the plants to be sampled. The plants are then shaken or beaten with a wooden stick. The dislodged insects fall on the cloth and can be collected. While sampling for fast moving insects it is advised that an aspirator be used for collecting.

iv) *Windowpane traps*: Flying coleoptera (beetles) can be sampled using windowpane traps. It simply consists of a vertical pane of glass with a trough of preservative beneath it (Fig. 7.7). Any insect that hits the glass and reacts by falling is caught.

This trap is particularly useful for determining the direction of flight and can also provide information on the timing of the dispersal flight. Trap catches are affected by rain and other weather conditions and position and height of the trap in the field.

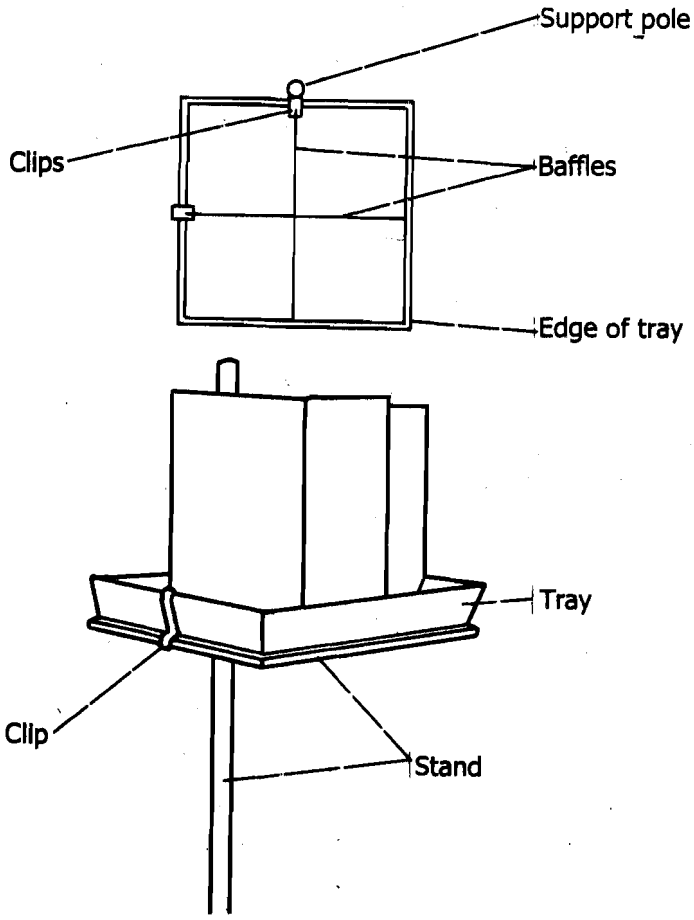

Fig. 7.6: Water trap with baffle.

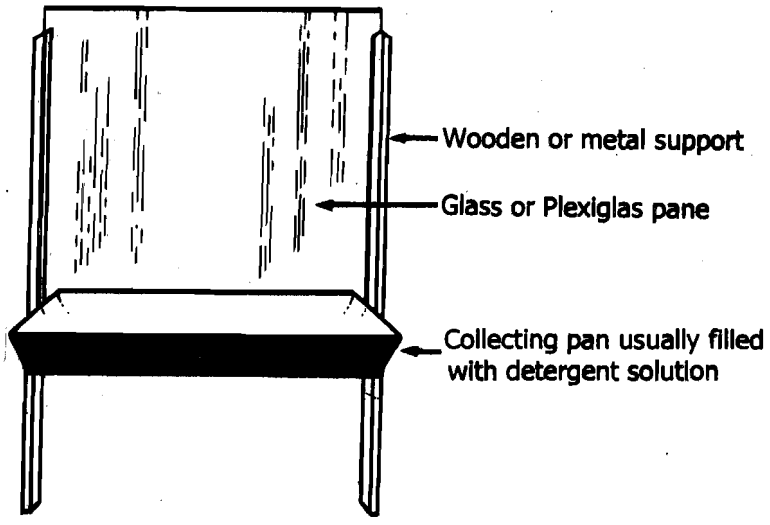

Fig. 7.7: Windowpane trap.

v) *Sticky traps:* Sticky trap is the modification of the windowpane traps. In this the surface of the glass or some other surface is covered with some substance sticky enough to hold the pest when it hits instead of letting it fall into the preservative

(Fig. 7.8). Sticky traps can be used for many species they cannot be taken with windowpane trap e.g. Yellow Sticky traps for aphids in mustard.

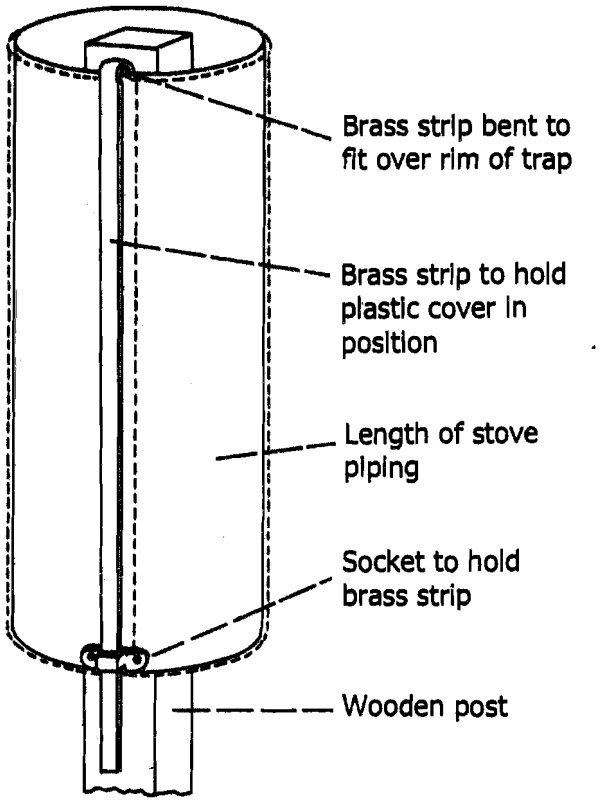

Fig. 7.8: Cylindrical sticky trap.

vi) *Malaise traps:* A malaise trap consists of a tent made of netting with one open side into which is placed a smaller container at the highest point (Fig. 7.9). The insects either crawl or fly through the open side. Most of the insects crawl up the netting once inside and these can be caught. These traps work best for active species such as adult flies and bees and wasps. The traps are unsuitable for insects as small as aphids because the screen mesh needs to be so fine that shelter effects occur and airflow through the trap is interrupted.

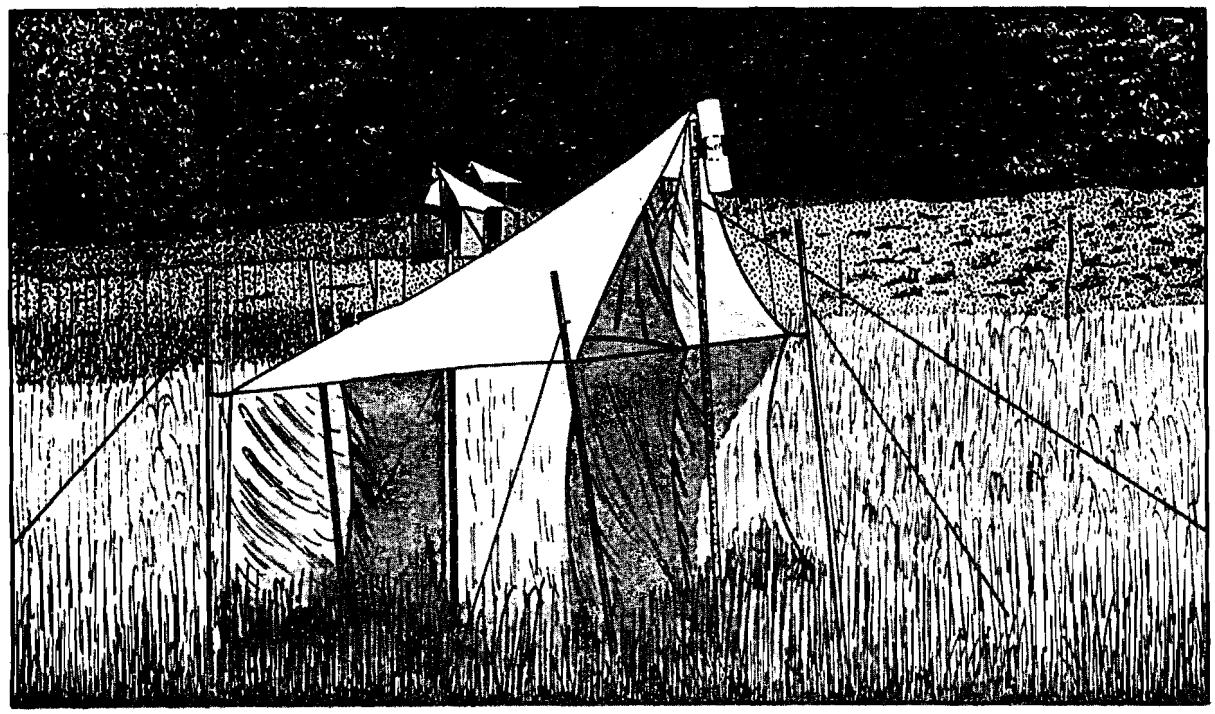

Fig. 7.9: Malaise trap.

vii) *Pitfall traps:* Pitfall traps are used for trapping species that roam the soil surface such as ground beetles, spiders and collembolans. These are simple to construct. These consist of smooth-sided containers e.g. glass jars sunk into the ground (Fig. 7.10). These must be protected against the predators, which will devour the catch. These should also be protected from rain.

Pitfall trap is used for sampling insects moving on ground.

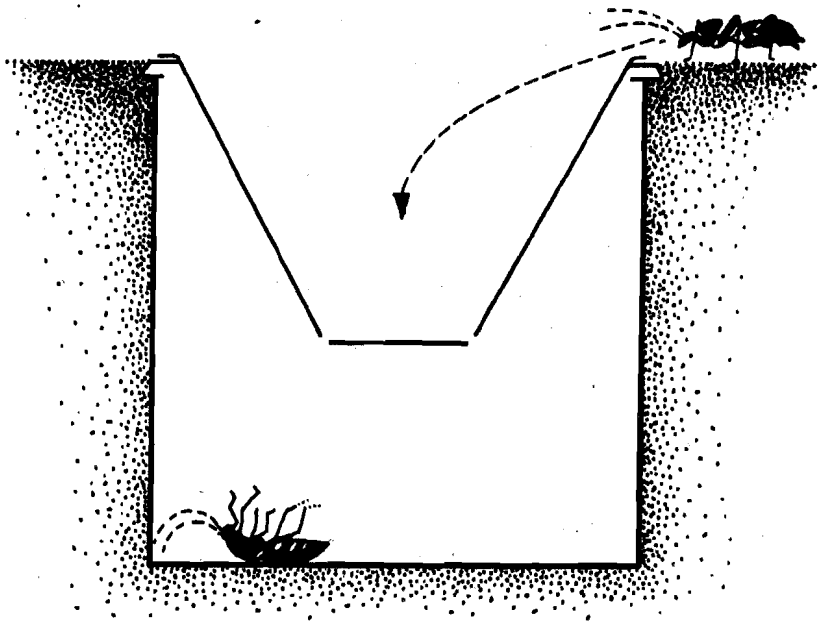

Fig. 7.10: Pitfall trap.

viii)*Suction traps:* Suction traps capture the insects by sucking them. A motor creates the suction. Suction traps can be portable or fixed. For small insects and restricted habitats such as base of rice plants, a hand held portable battery-driven car vacuum cleaner type of sampler with a 2.5 cm diameter nozzle is useful. For larger areas a variety of bigger electric machines are available. The Johnson-Southwood sampler with a 3 cm diameter nozzle, Univac sampler with a 6 cm diameter nozzle and D-vac machine with a 13.5 cm diameter nozzle are all examples of larger portable machines. Insects in flight can be sampled with fixed suction traps. Small suction traps for catching insects in crops have been described by Johnson (1950) and Taylor (1951). The exposed cone type (Fig. 7.11) usually has a 30 cm fan through which air and insects pass into a copper gauge cone at the end of which is a collecting tube. Smaller fans can be used only in very sheltered sites as cross-winds in excess of 4 m/s significantly reduce the air intake of the fan. The catch can be separated at predetermined time intervals by a disc mechanism so that the period over which flight occurs can be studied. Other traps with an enclosed cone have been designed so that insects do not pass through the fan. Suction traps undoubtedly provide the best independent sampling method for measuring absolute population density in nearly all weather conditions.

ix) *Light traps:* Attraction of insects towards light can be exploited to trap them into a malaise trap, a suction trap or some other type of trap. The most common device exploiting visual behaviour of insects are light traps. Light traps have long been used to sample agricultural pests. Basically these consist of a light above a funnel and a container below to collect the catch. The lamp is usually surrounded by baffles above a funnel dam by which insects fall into a container. Various design of traps have been in vogue e.g. Rothamsted trap, Robinson trap etc. (Fig. 7.12). A typical light trap uses an ultraviolet fluorescent tube as a source of light. The catch from light trap will vary with the height of the trap above the ground, the light intensity, the angle of the light and such natural factors as temperature, wind and amount of moonlight. Smaller traps with balling-operated lamps are now

available for sampling mosquitoes and can be placed in crops remote from a mains electricity supply. Light traps are mainly used to assess the number of pest species, to monitor relative changes in their population size and to relate them to other methods of assessment as an aid to pest management.

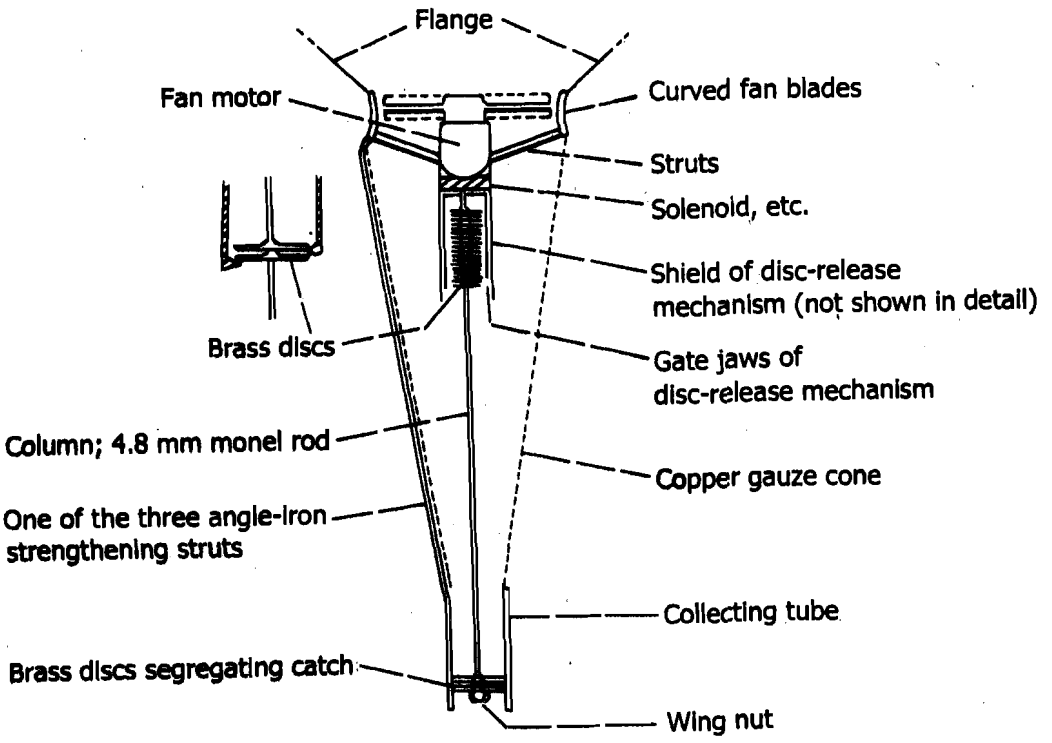

Fig. 7.11: Suction Trap (Exposed Cone Type).

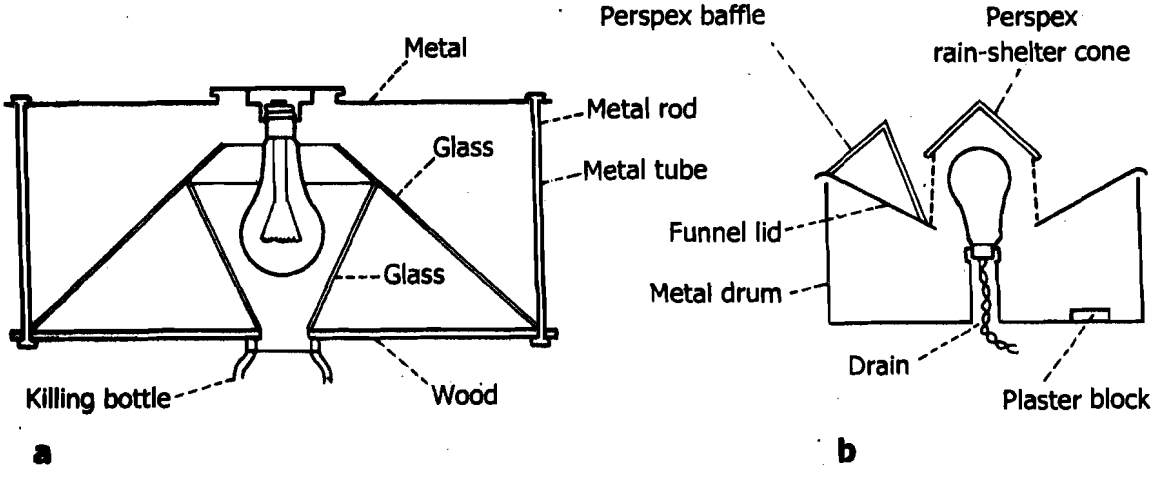

Fig.7.12: Light traps. a) Rothamsted, b) Robinson.

x) *Attractant traps:* The species that are not attracted to light may be trapped instead by using an attractant or bait. Attractant trap may be based on crop itself. Besides natural or synthetic chemicals on an attractant derived from pest itself can be utilized. Banana weevil is assessed by using cut pieces of banana stem. Rhinoceros beetles are assessed by cut pieces of coconut stem and tomato pests by pieces of tomato. Sugar or molasses are used to attract fruit sucking moths and protein hydrolysate is used in fruit fly traps. Sex attractants or sex pheromones are being used for the management of many moth pests of agricultural crops.

xi) *Pheromone traps:* Sex pheromones of lepidopteran pests are now used on an increasing scale to detect early infestations or to monitor populations and assist in the timing of pesticide application. The main advantage of pheromone traps over light traps is that normally only the target species is attracted and a trained entomologist is not needed to identify the catches. No power is required so pheromone traps are easier to operate and can be placed in remote areas.

Careful studies of the behavioural response of the insect in relation to the shape of the trap and method of pheromone release are needed to optimize the sensitivity of the trap. In India, *Heliothis armigera* has been very effectively trapped in a simpler trap consisting of a circular top over a funnel to which a polythene bag is attached to collect the moths; catches were improved with a smaller funnel attached to the lower surface of the top (Fig. 7.13).

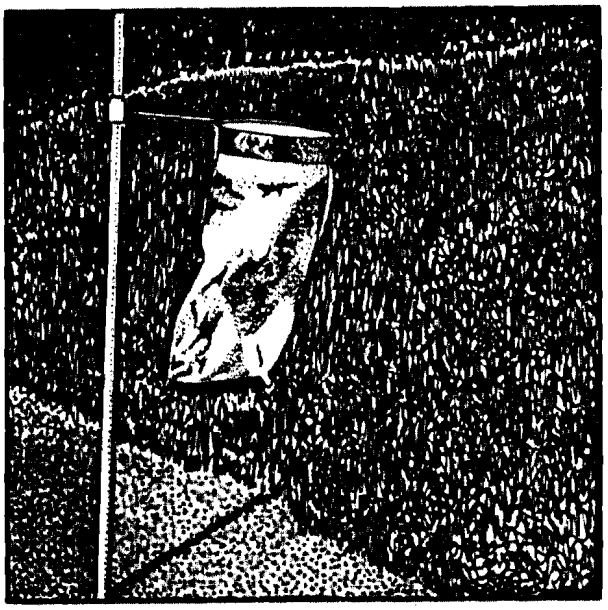

Fig. 7.13: *Heliothis* pheromone trap in India.

7.7.3 Population Indices

Pest damage is a population index.

Population indices are not direct insect counts but are counts of their products like frass, webs, exuviae, nests or their effects such as plant damage. In these cases these effects are easily recorded than the population itself. The pest product most often sampled is frass or excreta of lepidopterous defoliators of forests. The frass is collected by placing a box or funnel under the tree. From this relative estimate of population can be made. Insect nests can also be sampled easily. The nests of caterpillars can be counted to get an estimate of pest density.

The incidence of pests can also be recorded in terms of their damage. For example, incidence of cutworms or white grubs is recorded in terms of cut or missing plants. The dead hearts or white heads in rice reflect the intensity of rice stem borer in rice. Leaf area of plants removed by defoliators can also be measured. The damage to maize cobs by borers, to gram pods by gram pod borer, to sorghum seeds by midges, and to cotton bolls by bollworms can be easily recorded. The use of population indices is justified only if they have been fully validated and they provide considerable savings in time and labour.

SAQ 6

i) What is a sample unit?

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ii) Name different types of population estimates

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iii) What is a relative population estimate?

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iv) What are population indices?

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7.8 METHODS OF SAMPLING

The way or the mode in which sample units are selected in the field is called the **sampling method** or **sampling technique**. Random sampling has been widely used to sample pest and natural enemy population in the field. In random sampling every unit has an equal chance of inclusion in the sample. There should not be any bias in the selection of sample units. Sometimes by observing more pests of the adjoining plant, we may be tempted to reject the actual sample unit. This should never be done. The random selection of units is ensured by using random number table. The position of the sample unit is selected on the basis of two random numbers, which show distances along two coordinates. The point of intersection of the coordinates indicates the location of the sample unit. The drawback of this method is that as a matter of chance all sample units sometimes may be selected from the same area of the field. In place of random number table, random selection is also done by predeciding the position of sample units. For example, in case of mustard, maize or rice where plants are quite apart, one can decide to examine a particular plant in a particular row of the crop. The plants can either be selected and tagged before the initiation of pest incidence on the crop and all observations are then recorded on these tagged plants or the plants can be selected at each sampling. In case of crops like wheat where plants are very close to each other, the random selection is ensured by selecting tillers after walking a definite number of steps in the field. These methods are less random than the use of random number table but are easier and more practical. There are four different types of random sampling.

1. Simple random sampling
2. Stratified random sampling
3. Systematic random sampling
4. Sequential sampling

7.8.1 Simple Random Sampling

Random means indiscrimination in selecting sample units of a sample

Simple random sampling can be adopted for estimating pest population when pest habitat for example a crop field is homogenous in terms of slope, fertility and sunshine availability etc. In this whole crop field is considered as single unit. The sample units are then selected randomly throughout the field. The mean density is then worked out by dividing the total population observed on all sample units by number of sample units.

7.8.2 Stratified Random Sampling

It is generally seen that fields are not uniform and there are differences in slope and fertility among different parts of the field or some areas may be shady. Therefore, the

field cannot be treated as a single unit. Based on these differences the condition of the crop would vary which, in turn, would influence distribution of the pest. For example, areas receiving more fertilizer or water due to presence of slope in the field would have healthy crop and may attract pest population more. In such a situation the field is first divided into uniform strata. The sample units are then selected randomly from each stratum in proportion to its area in relation to total area. For example, suppose a field of 1000 m^2 comprises of 4 strata of 200, 400, 300 and 100 m^2 and 100 sample units are to be drawn from it. On the basis of the area of different strata 20, 40, 30 and 10 sample units will be drawn from first, second, third and fourth stratum. This type of sampling is efficient is it increases precision and reduces the variance between sample units.

7.8.3 Systematic Sampling

In systematic random sampling first sample unit is selected randomly. The subsequent sample units are then selected at a fixed interval. For example if there are one hundred plants in a row and by random selection first plant selected happens to be 4^{th}. We will then get a systematic sample by selecting 9^{th}, 14^{th}, 19^{th}, 24^{th} etc plant at an interval of 5 or 14^{th}, 24^{th}, 34^{th}, 44^{th} sample unit at an interval of 10 sample units. We may face a problem when the selected plant occurs to be diseased or damaged.

7.8.4 Sequential Sampling

In Sequential sampling sample size is not fixed.

In random sampling sample size i.e. number of sample units required to estimate pest population is fixed. But in sequential sampling the sample size is not fixed. The drawing of next sample depends upon the decision achieved in the last sample. This type of sampling is very useful for taking control decisions in the field. This plan is formulated by taking into consideration the distribution of the pest and its economic injury level. Therefore if pest population approaches economic injury level then the plan suggests adoption of control measures otherwise not. The number of samples taken varies with the size of infestation, and sampling stops once it is known that pest population steadies at a certain density.

7.9 PEST FORECASTING

Forecasting means looking forward. The information needed for forecasting is:

- Factors controlling population behaviour
- Present position of the population

The forecasting involves the comparison of factors known for controlling the population behaviour with the factors affecting the present population. Prior information regarding pest density in crop season helps farmers to make necessary management to deal with pest situation. Population of pests can be predicted through **regression models** or **population dynamics models**.

Regression models represent the relationship between pest population and various weather factors such as temperature, humidity, rainfall, wind velocity etc. On the other hand, pest population dynamics models represent different pest growth processes such as eggs, larval, pupal and adult development in mathematical equations.

The pest forecasting system comprises of **surveillance** and **monitoring** with a computer data-base on weather predictions, cost and efficiency of various management tactics, prices of inputs, farm produce etc. Pest forecasting plays very important role in timely management of pests. There is need to develop reliable pest forecasting models.

Pest damage is a function of pest population density.

7.10 POPULATION DYNAMICS

Population of pests does not remain same in different seasons or years but it fluctuates around general equilibrium position of the pest. The change in the population density of a pest is called **population dynamics**. The general equilibrium position of the pest can be defined as the average population density of the pest over a long period of time. The fluctuation in the pest population occurs due to change in the intensity of different mortality factors. As already discussed, mortality factors are both abiotic and biotic. Meteorological factors such as temperature, humidity, rainfall, wind etc. constitute abiotic or physical factors. On the other hand, parasitoids, predators and pathogens are included in biotic factors. Of all the mortality factors, one mortality factor is most closely associated with changes in pest population in different generations or years. This factor is called the **key mortality factor**. The key mortality factor is by and large responsible for population dynamics of a species.

SAQ 7

i) What are the different types of pest sampling methods?

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ii) What is systematic sampling?

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iii) What is general equilibrium position of a pest?

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iv) What is population dynamics of a pest?

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7.11 ASSESSMENT OF CROP LOSSES DUE TO PESTS

Crop loss due to pests is a function of pest population density except in case of vectors. More the pest population more is the loss inflicted by pests. But in case of vectors, which transmit disease pathogens, population density is not important. Even a few individuals of vectors such as whitefly, *Bemisia tabaci*, a vector of yellow mosaic virus, can transmit the disease to the entire field. The pests damage the crop mainly due to their feeding habits and to a lesser extent due to their oviposition habits. The types of damage to the plant by pests are as varied as their feeding habits.

7.11.1 Categories of Pests

Broadly pests can be categorized as

- direct pests and
- indirect pests

Direct pests attack yield-producing part of the plant directly. Even small population of such pests may incur heavy losses. For example, gram pod borer, pink bollworm in

cotton, fruit flies, cauliflower head borer, brinjal shoot and fruit borer, codling moth in apples, maize ear worm and rice stem borer are some of the direct pests. The damage due to such pests is recorded as number of damaged units per plant or per unit area. The percent damage due to pest can also be worked out if total number of units per plant or per unit area is known.

Indirect pests infest those plant parts, which may be physiologically contributing to the yield but don't produce by themselves. Pests like defoliating beetles, grasshoppers, leaf folders and leaf miners etc. fall under this category.

7.11.2 Importance of Crop Loss Assessment

Assessment of losses due to pests is important to know their relative importance. More the losses caused by a pest more important it is and its management deserves more attention. Information on crop loss is also useful to know the quantum of preventable loss and expected increase in the yield. Crop loss due to pests may be defined as the **reduction caused in the attainable yield**. There are three levels of production viz. potential , attainable and actual production. Potential production is determined by weather and crop genotype. There is no constraint of nutrients and water. Also there is no pest stress. This type of production is obtained on very small acreage especially in experimental plots. In the presence of nutrient and water stress, the potential yield of the crop gets reduced to attainable level. The nutrients and water are called yield reducing factors. Here also there is no pest stress. This is the yield, which is harvested in farmers field with effective plant protection measures. Besides water and nutrient stress, when there is pest stress also, the attainable yield declines to actual yield. The pests are called yield-reducing factors. Therefore, the difference between attainable yield and actual yield is the loss attributed to pests. Through pest management we want to bridge this gap as far as possible.

Pests are known as yield reducing factors. The reduction in yield caused by pests, compared with plants in the same environment without the pest, is called crop loss.

Several pests may occur on the crop in the field simultaneously. We can prepare the pest profile for a crop. Pest profile shows the activity of different pests during different stages of the crop. This may help to understand the relative importance of different pests or to find out the most important constraints in the production of the crop. Similarly damage period of activity of the pest.

7.11.3 Types of Crop Losses

Crop losses may be divided into

- losses caused before harvest in the field and
- losses during storage or during processing

Loss is not only quantitative, it may be qualitative also. The presence of insects on fruits or vegetables may reduce their acceptability to consumers. The presence of *Spodoptera* or aphids in cauliflower reduces their value. Presence of scab lesions on apples reduces their market value. Cotton stainer, red cotton bug reduces the quality of lint. Aphids and other sucking insects make flowers or fruits sticky, which spoils their appearance. Pests cause losses in crop yield by (i) destroying photosynthetic area of leaves (ii) destroying storage contents in organs such as potato or sweet potato or in sugarcane stems (iii) damaging reproductive parts such as flowers, fruit or seed and (iv) interrupting water and nutrient uptake through roots

Insecticides can cause phytotoxic or phytotonic effects in plants.

7.11.4 Methods of Crop Loss Assessment

Crop losses due to pests may be assessed by

- Utilizing natural infestation levels of pests
- Use of insecticides to control pests
- Use of physical barrier to prevent pest attack on the crop and
- Use of resistant and susceptible varieties

1. **Loss assessment under natural infestation**: The crop plants in the field are not uniformly infested by the pests. Some plants are infested heavily, some have low populations and some may be free. In such situations the data on yield of several infested plants and several uninfested plants can be collected. The average yield of unifested and infested plants can be worked out. The difference between these two yields will be the loss incurred by the pest. The percent yield reduction can then be worked out as follows.

$$\text{Per cent reduction} = \frac{\text{yield of uninfested plants-yield of infested plants}}{\text{yield of uninfested plant x 1000.}}$$

Care should be taken to include the plants with all levels of pest infestation in the sample. Problems may arise when other pests are also present on crop plants. Walker has proposed six types of relationship between intensity of infestation and yield (Fig. 7.14 a-f).

a) In a few cases yields may be reduced proportionally as infestation increases
b) but a sigmoid response is most common
c) severe damage due to a very low pest population may occur when a few vectors transmit a virus or other disease-causing organisms
d) yield may also be logarithmically related to the number of pests
e) or increases with a light infestation
f) In some experiments an increase in infestation has produced no significant change in yield, possibly because adequate compensation by the plant is possible.

Conway (1976) has classified pests in relation to the spectrum of ecological strategies decribed by Southwood (1976), and has given examples of insect pests which can be regarded as *r* or *K* pests (Table 7.1 and Fig. 7.15).

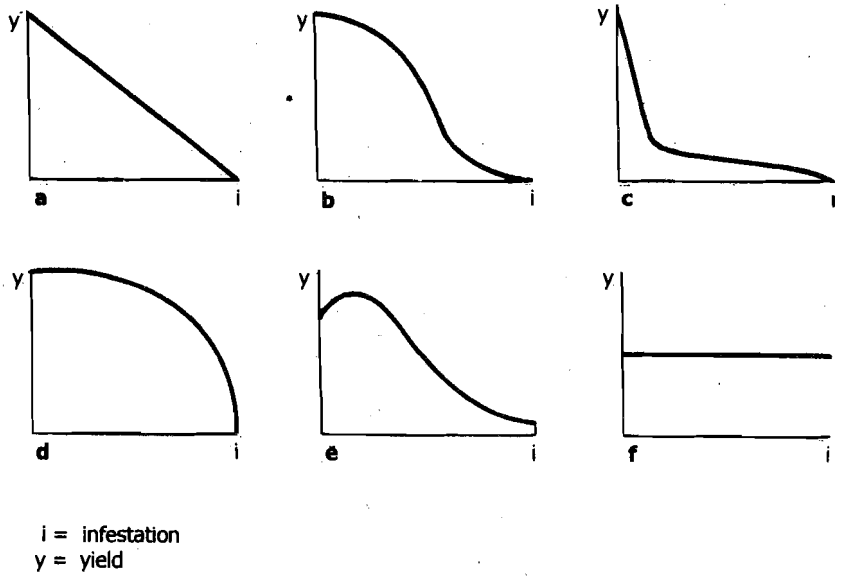

Fig. 7-14: (a to f) Variations in yield response to infestation

At one end of the spectrum *r* pests have a high potential rate of reproduction, so populations can increase very rapidly as soon as environmental conditions i.e. food supply, temperature, humidity and other factors are favourable. Populations can rebound rapidly even when natural enemies or disease cause heavy mortality. Such pests, e.g. aphids, are readily dispersed and are successful at finding and exploring

new habitats, resulting in massive outbreaks which can cause extensive damage before the natural enemies can act. Migrant pests such as locusts and some armyworms are *r* pests. In contrast *K* pests have a relatively slow rate of increase. The competitive ability of *K* pests is greater, but they prefer more specialized food. Low populations are regarded as important; thus codling moth is a major pest of orchards as there is a demand for high-quality, unblemished apples.

Important pests are often either *r* or *k* strategists, but most pests are intermediate between these extremes. Populations of intermediate pests are normally regulated by natural enemies.

Table 7.1: Some important insect pests and their characteristics.

Species	Fecundity per females (approx)	Generation time (approx)	Pest features
r pests			
Desert locust (*Schistocerca gregaria*)	400	1-2 months	Periodic outbreaks which defoliate any crop
Black bean aphid (*Aphis fabae*)	100	1-2 weeks	Wide range of crop plants including beans and beet
Housefly (*Musca domestica*)	500	2-3 weeks	Feeds on organic matter
Black cutworm (*Agrotis ipsilon*)	1500	1-1.5 months	Attacks seedlings of most crops
K pests			
Rhinoceros bettle (*Oryctes rhinoceros*)	50	3-4 months	Adult feeds on apical growing point of coconuts often killing pod
Tsetse fly (*Glossina* spp.)	10	2-3 months	Vector of trypanosomiasis affecting man and cattle
Codling moth (*Cydia pomonella*)	40	2-6 months	Larvae damage apples and other fruit

Control technique appropriate for *r* pests was the use of pesticides, as this was the only method with speed and flexibility required to respond to an outbreak of the pests. Pesticides are also appropriate for *K* pests when very small populations cause considerable losses of revenue, but preference should be given whenever possible to alternative strategies such as cultural control and use of resistant varieties or animals (Fig. 7.15).

2. **Use of insecticides to control pest densities**: In this method some crop plots are completely protected from pests by applying pesticides. Other plots are allowed to be infested with natural infestation. The yields of both type of plots is recorded. The difference between the yield of protected crop and unprotected crop is the crop loss due to the pest. The percent yield reduction due to pest can be calculated from this data. Variable pest levels can also be generated in different plots by applying insecticides at different intervals. The variable pest levels will lead to variable yields in different plots. This yield and pest population data can be used to develop a mathematical relationship. This relationship can be then used in future to estimate crop yield based on pest population level present in the field.

There is one drawback with the use of insecticides that some insecticides may have growth promoting effect on the crop. In that case losses due to pests may be overestimated because difference between yield of protected and unprotected crop will be more.

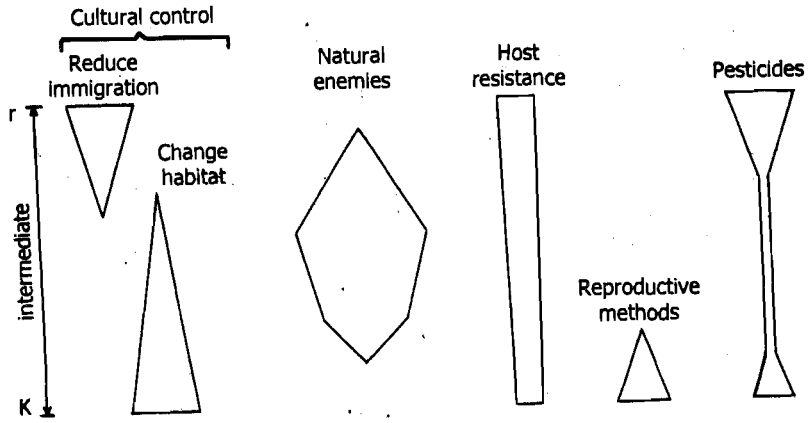

Fig. 7.15: Appropriate control strategies for pests categorized in terms of *r* – *K* continuum.

3. **Use of physical barriers to control pest densities**: In this method the crop is protected from pests by enclosing plants, plots or even fields in cages or nets. To provide uniform conditions for growth, the infested crop should also be covered with cages or other enclosures. But these cages should allow free movement of insects into and out of cages. On small scale pests may be removed by hand also. The yield of protected and infested crop is then determined and yield loss due to pests is worked out.

4. **Use of resistant and susceptible variety:** If susceptible and resistant varieties of a crop are available then they can be grown. The difference between the yield of two will be the loss due to pests. The yield potential of resistant and susceptible variety should be comparable for reasonable estimate of yield loss. Because if yield potential of resistant variety is less, then less loss will be attributed to the pests. But if yield potential of resistant variety is more, then more loss will be attributed to the pests.

SAQ 8

i) What are direct pests? Give some examples.

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ii) What is potential production?

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7.12 SUMMARY

In the unit, you have learnt that:

- Study of interrelations between living organisms with each other and their physical environment is called the ecology.
- Populations of different species together constitute biotic community. Continuous interaction of biotic community with physical environment gives rise to ecological system (ecosystem).
- Ecosystem is considered a holistic component of environment as it contains both the biotic community and physical (abiotic) components of environment. The interaction of biotic community with physical environment ensures continuous flow of energy and formation of well defined trophic structure in the community. Ultimate source of energy to the universe is sun. Suns energy is trapped by green plants and then heterotrophs draw their energy directly or indirectly from plants.
- The flow of energy from one species to another through the process of eating and getting eaten in return is called food chain. Interlinking of food chains is called food web. Food web formation lends stability to ecosystem. As the energy passes from one trophic level to another, 90 percent of it gets lost. With decrease in availability of energy there is decrease in biomass at higher trophy levels.
- The organisms possess very high biotic potential but it is never realized in nature due to environmental resistance. The environmental resistance consists of all biotic and biotic mortality factors which kill the organisms.
- Population of organisms can grow either in J- or S-shaped manner. J-shaped growth is exhibited by most pest species, which grow very fast on finding resources. Population of such species is controlled by abiotic mortality factors. On the other hand S-shaped population growth is shown by species, which grow slowly and their populations are controlled by biotic mortality factors.
- Population estimation is necessary to know efficacy of control measures and whether population has reached economic damaging level or not. Sampling is used to estimate pest population in the field. Sampling methods such as simple random sampling, stratified random sampling and sequential sampling are widely used to assess pet population on crops.
- Pest population estimates are of three types viz. absolute estimates, relative estimates and population indices. Relative estimate are cheaper and provide sufficient information regarding effectiveness of control measures.
- Losses caused by pests are generally function of their population density. Estimation of losses due to pests helps to know their relative importance and quantum of avoidable losses. Loss can be assessed either by comparing yield of infested and uninfested plants under natural infestation or by excluding pests by chemicals or physical barriers and then comparing yield of infested and uninfested crop or by comparing yield of resistant and susceptible varieties.
- Pest depending on their characteristics are classified as r-pests and K-pests. There are different control strategies for r and K-pests.

7.13 TERMINAL QUESTIONS

1. What is autecology?

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2. What is an ecosystem?

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3. Why study of the environment at ecosystem level is called holistic study?

4. Differentiate between a grazing food chain and a detritus food chain.

5. Differentiate between a herbivore and a carnivore.

6. Differentiate between an autotroph and a heterotroph.

7. Differentiate between a parasitoid and a predator.

8. How much energy is lost during transfer from one trophic level to another?

9. Why there is decrease in biomass of organisms with increase in trophic level?

10. What is an ecological succession?

11. Does succession reach climax in agroecosystem?

12. Differentiate between J-shaped and S-shaped population growth.

13. Why is there less diversity in an agroecosytem?

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14. What is biotic potential?

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15. What is environmental resistance?

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16. Why exotic pests realize higher population in new environments?

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17. What is the mode of action of biotic mortality factors?

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18. Why is the sampling required?

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19. What is a sample?

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20. What is an absolute population estimate?

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21. What is stratified random sampling?

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22. What is sequential sampling?

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23. What is a key mortality factor?

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24. Why do we determine crop losses due to pests?

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25. Differentiate between attainable yield and actual yield.

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26. List eight relative methods of population measurement and describe any two in detail.

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27. Differentiate between r and K pests.

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28. What is pest forecasting?

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7.14 ANSWERS

Self-assessment Question

1. i) Study of relationships between living organisms on one hand and their physical environment on the other is called ecology.
   ii) Ecology of several species or in other words ecology of biotic community is called synecology.
   iii) Habitat may be defined as a place where an organism lives.

2. i) Number of individuals of a species at a particular place at a particular time is called population.
   ii) Assemblage of populations of all species in a habitat is called biotic community.
   iii) Similar types of ecosystems together are called a biome.

3. i) Transfer of food energy from one species of organisms to another by the process of eating and getting eaten in return is called food chain.
   ii) Interlinking of food chains is called a food web.
   iii) The feeding position of an species of organisms in food chain is called trophic level.
   iv) Herbivores such as insect pests, cow, buffalo etc. are called primary consumers.

v) Tertiary consumers are hyperparasites, which feed on useful natural enemies so they are harmful.
vi) Different communities which exist in an habitat during ecological succession are called seral stages.
vii) Ecological succession at a place where no community existed earlier is called primary succession.

4. i) These are minute floating plants usually algae, distributed throughout the water as deep as light penetrates.
ii) The animals which live at the bottom of water bodies are called benthos.
iii) In forest ecosystem, trees, shrubs and herbs are found.
iv) Agroecosystem can be defined as an ecosystem, which is actively manipulated by man for getting maximum production.

5. i) Population growth forms are J-shaped and S-shaped.
ii) Inherent capacity of a organism to reproduce is called reproductive potential.
iii) The capacity of organism to utilize natural resources as its food is called nutritive potential.
iv) Living organisms such as parasites, predators and pathogens, which kill other organisms, are called biotic mortality factors.
v) Pests which get introduced in to a new country from abroad due to quarantine negligence are called exotic pests.

6. i) Basic unit such as ground area or plant part like leaf, panicle, stem or whole plant itself on which pests are counted is called a sample unit.
ii) Different types of population estimates are absolute estimate, relative estimate and population indices.
iii) Relative estimate represents some fraction of actual pest population in an area.
iv) Population indices refer to pest products such as frass, nests or their damage.

7. i) Different types of sampling methods are simple random sampling, stratified random sampling, systematic sampling and sequential sampling etc.
ii) In systematic sampling, first sample unit selected randomly but subsequent units are selected at regular interval.
iii) The general equilibrium position of the pest can be defined as the average population density of the pest over a long period of time.
iv) The change in the population density of a pest during different generations is called population dynamics.

8. i) Pests which damage the yield producing parts of crop directly such as gram pod borer, brinjal fruit borer, ber fruit fly etc.
ii) Production level of crop when there is no nutrient, water and pest constraint

TERMINAL QUESTIONS

1. Ecology of single species of organisms is called autecology.
2. A system developed due to continuous interaction of biotic community with physical environment is called an ecosystem.
3. Ecosystem consists of both biotic community and abiotic components and therefore study at ecosystem level is called holistic study.
4. Grazing food chain starts from green plant and moves to herbivore, primary carnivore, secondary carnivore etc. Detritus food chain on the other hand starts from dead organic matter (detritus) and moves on to microorganisms, predators etc.
5. An organism feeding on plants is called a herbivore while an organism feeding on other animals is called a carnivore.
6. Organisms, which can prepare their own food, are called autotrophs while organisms feeding on other organisms are called heterotrophs.

7. A parasitic insect which differs from true parasites as is called parasitoid. Its size is almost equal to its host and it does not kill the host instantly, it completes its life cycle partly on the host. Predator is bigger than its prey. It kills its prey instantly and is free living throughout its life.
8. About 90 % energy is lost during its transfer from one trophic level to another.
9. Because there is 90 % loss of energy at each trophic level, therefore there is decrease in biomass with increasing trophic level.
10. A systematic and predictable change in biotic communities of a habitat is called an ecological succession.
11. Ecological succession does not reach climax stage in an agro ecosystem because it is terminated with harvesting.
12. J-shaped population growth shows steep rise in population because there is no environmental resistance in the beginning. When environmental resistance appears, the population crashes. On the other hand, in S-shaped growth, the population grows slowly as there is environmental resistance from very beginning. The population does not crash here but fluctuates around carrying capacity.
13. Agro-ecosystem is less diverse because plants other than crop plants are removed.
14. Inherent capacity of an organism to reproduce, survive and multiply is called biotic potential.
15. All the environmental factors, which kill the individuals of a species, constitute environmental resistance.
16. When exotic pests come into a new country, their natural enemies are left behind. Therefore they encounter less environmental resistance and assume large populations.
17. Biotic mortality factors can act in density dependent manner or density independent manner.
18. In field there is large area and very large number of crop plants. We cannot count insects on all the plants. Therefore sampling is resorted to.
19. Smallest plant part or area on which insects are counted is called a sample unit. Collection of sample units constitutes a sample.
20. Counting of all individuals of a species per unit area is called absolute population estimate.
21. In stratified random sampling, a non-uniform field is divided into homogenous strata. Samples are then selected from each stratum in proportion to its area.
22. Sequential sampling is formulated by taking into consideration, spatial distribution of pest and economic injury level. In this sample size is not fixed. It is very useful for taking management decisions against pests.
23. Mortality factor, which is responsible for population dynamics of a species, is called a key mortality factor.
24. We determine crop losses due to pests to know their relative importance and also to know the quantum of avoidable losses.
25. Attainable yield obtained when there is constraint of water and nutrients but pest stress is not there. On the other hand actual yields is obtained when besides water and nutrient constraints pest stress is also there.
26. Refer Sec. 7.7.2.
27. Refer Sec. 7.11.4
28. Refer Sec. 7.9