PRINCIPLES AND CONCEPT OF INTEGRATED PEST MANAGEMENT

History of Pest Management

- 2500 BC First records of insecticides; Sumerians used sulfur compounds to control insects and mites.
- 200 BC Romans advocated oil sprays for pest control.
- 300 AD First records of biological controls; Chinese used. predatory ants in citrus orchards to control caterpillar and beetle pests.
- 1880 First commercial spraying machine.
- 1930 Introduction of synthetic organic compounds for plant pathogen control.
- 1940 First successful use of an entomopathogen; Milky Spore (*Bacillus popillae) used to control Japanese beetle.*

- Supervised insect control –

Shortly after World War II, when synthetic **insecticides** became widely available,

entomologists in California developed the concept of Supervised Control.

- It is an alternative to calendar-based insecticide programs.
- Supervised control was based on a sound knowledge of the ecology and analysis of projected trends in pest and natural-enemy populations.
- Integrated control-

Supervised control formed much of the conceptual basis for "integrated control" that

University of California entomologists articulated in the 1950s.

- Integrated control sought to identify the best mix of chemical and biological controls for a given insect pest.
- The adage of "if a little works, a lot will work better" was the major premise for applying chemical to address pest problems on the farm and around the home
- Ecological Backlash –
- As early as the 1950's, pesticide-induced problems such as pest resurgence, pest replacement, and pesticide resistance caused problems in agriculture.

- Pest resurgence = In 1959, scientists discovered that aphids could be better controlled by reducing the amount of pesticide used because the pesticides were killing aphid predators as well as the aphids themselves, causing large-scale pest resurgence (Stern, et al., 1959).

Pest Management –

- The concept of 'pest management' was proposed in 1961 (Geier and Clark, 1961)
- For the reduction of pest problems actions are selected after the life systems of the pests are understood and the ecological and economic consequences of these actions have been predicted, as accurately as possible, to be in the best interests of mankind.
- **Widespread pest resistance in 1950's to DDT and other** Pesticides
- **Environmental Awareness d**uring the 1960s – new awareness of ecology and the environmental impact of pesticide pollution resulted from a public outcry about environmental contamination found in the air and foul water found in rivers and streams.
- By 1962, when "Silent Spring" by Rachel Carson was published, serious concerns about the disadvantages of pesticide use were widely raised .
- Rachel Carson and others suggested that pest control methods other than chemical pesticides should be used in order to protect wildlife, human health and the environment.
- Public pressure led to government legislation restricting pesticide use in many countries resulting in ban of DDT and other pesticides.
- **Integrated Pest Management-** In 1967 the term IPM was introduced by R.F. Smith and R. van den Bosch.
- The term IPM was formalized by the US National Academy of Sciences in 1969.
- IPM was adopted as policy by various world governments during the 70's and 80's, including the USA (1972)
- **1970's-1980's IPM adapted for managing pests of landscape trees and shrubs in Urban Areas**
- In 1985 India declared IPM as official Ministerial Policy.
- **IPM and its evolution**-

Over the years IPM underwent several changes in its focus and approaches.

- Some of the key approaches are
- **Damage threshold –**

The basic IPM principle relied on the damage boundary/ economic damage relationship i.e no injury level below the damage boundary merits suppression, but injury predicted to result in economic damage does.

- **Economic Injury Level-** The EIL is the most basic of the decision rules; it is a theoretical value that, if actually attained by a pest population, will result in economic damage.

ECOLOGICAL ENGINEERING FOR PEST MANAGEMENT

- Ecological Engineering explores the ecological engineering strategies based on the management of habitat to achieve pest suppression.

- It could be argued that all pest management approaches are forms of ecological engineering, irrespective of whether they act on the physical environment (e.g., via tillage), chemical environment (e.g., via pesticide use) or biotic environment (e.g., via the use of novel crop varieties).

- However, the use of cultural techniques to effect habitat manipulation and enhance biological control most readily fits the philosophy of ecological engineering for pest management.

Plant protection in India and most of the developing countries is mainly based on the use of pesticidal chemicals. Chemical control is one of the effective and quicker method in reducing pest population where farmer gets spectacular result within a short time. However, over reliance and indiscriminate use of pesticides resulted in a series of problems in the Agricultural ecosystem mainly, the development of resistance in insects to insecticides, resurgence of treated population, out break of secondary pests into primary nature, environmental contamination and residue hazards, destruction of natural enemies of insect pests, expenses on pesticides, equipment, labour etc. All these problems contributed to a new way of thinking concerning pest control practices, i.e. the integrated approach of pest control. This was first proposed by Stern and his colleagues for integration of biological and chemical control measures.

This is not altogether a new concept. It was practiced before the advent of modern chemicals. Dates of planting of a crop were carefully studied to ensure that a crop was not being planted when it would encounter severe pest problems, cultural practices such as ploughing after harvest, timely weed control, well timed irrigation and a reduced use of fertilizers all contributed to reduce pest population. Most of these methods were curtailed when modern pesticides become available, it was thought that these chemicals alone could control pests, but now we know that this is not possible, and the single method of approach to pest control is not feasible. Hence, we have to form an integrated approach in pest management. IPM. "Integrated Pest Management is an ecological approach in which utilization of all available techniques of pest control to reduce and maintain the pest population at levels below economic injury level". Hence the new concept or approach is based on the principles of managing the pest rather than eradicating them. In other words pest management will be working 24 hours a day, every day of year. This is possible and must become a part of cultivators every day thinking and activities.

- Hence the new concept or approach is based on the principles of managing the pest rather than eradicating them.
- **AIM of Selected IPM strategies and prescriptions**
    - Promote natural controls.
    - Protect human health.

- Minimize negative impacts to non-target organism.
- Enhance the general environment.
- Be most likely to produce long-term, beneficial results.
- Be cost-effective in the short and long-term
- Be easily and efficiently implemented

- IPM fits best way in PHM
- Integrated Crop Management
- IPM + IWM + INM = ICM
- ICM + Soil Health Management = PHM
- Plant health is impacted by several factors such as soil health, nutrient management, abiotic stresses, pest population and ecological balance between pest and beneficial insects
- These factors vary from one agro-climatic region to another.
- In order to reduce crop losses due to pests, expertise is required in plant health management, the science and practice of understanding and overcoming biotic and abiotic factors that limit plants from achieving their full genetic potential as crops.
- ***"Subeezum sukshetram Dhyayate sampadate"***
- PHM = Here we take a broad view :
  - Considering not only IPM but also
  - Soil Health
  - Nutritional deficiency
  - Overall Plant health (Holistic view)
  - Seed to seed

Tools of Pest Management

The available techniques for controlling individual insect pests are conveniently categorised in increasing order of complexity as -

1. Cultural
2. Mechanical
3. Physical
4. Biological
5. Genetic
6. Regulatory
7. Chemical

Cultural methods or agronomic practices:

a. Use of resistant varieties

b. Crop rotation

c. Crop refuse destruction

d. Tillage of soil

e. Variation in time of planting or harvesting

f. Pruning or thinning and proper spacing

g. Judicious and balanced use of fertilizers

h. Crop sanitation

i. Water management

j. Planting of trap crops

1.Mechanical methods :

a. Hand destruction

b. Exclusion by barriers

c. Use of traps

3.Physical methods :

a. Application of heat - Hot water treatment

- Exposing of infested grain to sun
- Super heating of empty godowns at 50 degree C to kill hibernating stored grain pests.

b. Manipulation of moisture - Reduction of moisture content of grains helps to prevent from the attack of stored grain pests.

c. Energy - Light traps

4. Biological control :

a. Protection and encouragement of natural enemies

b. Introduction, artificial increase and colonization of specific parasitoids and predators.

- ❑ conservation of natural enemies
- ❑ Parasites and Parasitoids
  - ❑ Egg Parasitoids
  - ❑ Larval Parasitoids
  - ❑ Pupal Parasitoids

c. Propagation and dissemination of specific bacterial, viral, fungal and protozoan diseases.

5. **Genetic methods :** - Use of sterile male technique

6. **Regulatory methods :** - Plant quarantine

   a. Foreign quarantine

   b. Domestic quarantine

7. **Chemical methods :** - Use of attractants

   - Use of repellants
   - Use of growth inhibitors
   - Use of insecticides

Basic principles of Integrated Pest Management :

6. **Consideration of Ecosystem :**

Control of insect pest population is a function of the ecosystem itself by means of natural enemies and other factors. Knowledge of the role of the principle elements of the units is essential to an understanding of population phenomenon. The study of individuals is of prime importance, their biology behaviour response to other members of the same species and to other organisms and to biotic factors in the environment. The study of individuals offers a potent method for this analysis of population change. The most effective system for controlling pests can be derived only after understanding the principles responsible for the population fluctuation in the ecosystem.

7. **Pest Surveillance :**

Pest Surveillance and forecasting are having a vital part in the integrated pest management. Surveillance or monitoring means constant observation of a subject i.e., a crop or pest, and recording the factors observed, compilation of information obtained and prediction of future events about pest population. Hence pest surveillance comprises of three basic components.

a. Determination of the level of incidence of the pest species.

b. Determination of what loss the incidence will cause.

c. Determination of economic benefits or other benefits the control will provide.

The above information would be immense use in determining the need for a pest control measure. Mere presence of a few numbers of pest species should not be the criterion for pesticide application and there should be sufficient justification. Surveillance can provide the necessary information to determine the feasibility of a pest control programme. It should be a tool that assists pest management specialists in determining the actual factors that are involved in a pest build up, so that the specialists can determine practices that will manage these factors and prevent the initial build up of a pest.

3. Utilization of Economic Threshold Levels (ETL)

The level of pest population is very important consideration for taking up control measures. Pest population must be maintained at levels below those causing economic injury. The economic threshold is the pest density at which control measures should be determined to prevent an increasing pest population from reaching economic injury level. The determination of these thresholds is a pre-requisite to the development of any pest management strategy.

4. Application of minimum selective hazards :

The application of chemical measures to pest population has to be in such a manner that target pest populations are just kept below economic injury thresholds. By observation of this principle the development of resistant populations of pest is avoided or delayed, the possibility of resurgence of treated population is decreased, adverse effect on non target organism and amount of environmental contamination are reduced, and the cost of control is also lowered.

When insecticide treatments are deemed necessary special consideration should be given to (1) Effectiveness of the insecticide against most vulnerable life stage of the pest (2) Employing an insecticide that will cause least disturbance in the ecosystem. (3) Applying the insecticide in such a way that it will restrict its distribution to the area where it is needed.

Advantage of Integrated Pest Management :

1. Fits better in National Economy.

Pest control activities at present are mainly based on the application of chemical pesticides, quite a large proportion of which has to be imported. The expenditure envisaged for plant protection runs into crores of rupees even when only one or at the most two pesticide application are envisaged per crop. High yielding varieties show that many more pesticide applications are called for many crops if pest control has to depend only on the use of pesticide. Thus a time has come where Integrated Pest Management is not only advisable but also inevitable.

2. More efficient and cheaper method.

In IPM schedule efforts are made to utilize various methods of control including use of pesticides but some times and in some cases it is feasible to nip the trouble in the bud itself even by a mechanical campaign like destruction of egg masses of some pests or collecting the caterpillar stages. In such cases it envisages a lot of saving in the use of pesticides, this means saving of money and saving of foreign exchange and also the destruction of the pest before it has been able to inflict damage.

8. Avoid upsetting the balance of nature.

Chemical control has often been reported to upset the balance of nature at times leading to upsurge of new type of pest problem which did not exist before. The seriousness of mites in many parts of the world has occurred by the use of DDT. It is confidently expected that such adverse side effects will be much less as a result of integrated pest management schedule.

4. Minimises residue hazards of pesticides :

It is obvious that in an IPM schedule the use of pesticides will be considerably reduced, hence the pesticide residue hazards will also get automatically minimised.

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INTRODUCTION TO AGRO-ECOSYSTEM ANALYSIS (AESA)

The important rational planning for effective land use to promote efficient is well recognized. The ever increasing need for food to support growing population @2.1% (1860 millions) in the country demand a systematic appraisal of our soil and climatic resources to recast effective land use plan. Since the soils and climatic conditions of a region largely determine the cropping pattern and crop yields. Reliable information on agro ecological regions homogeneity in soil site conditions is the basic to maximize agricultural production on sustainable basis. This kind of systematic approach may help the country in planning and optimizing land use and preserving soils, environment.

India exhibits a variety of land scopes and climatic conditions those are reflected in the evolution of different soils and vegetation. These also exists a significant relationship among the soils, land form climate and vegetation. The object of present study is to delianate such regions as uniform as possible introspect of physiographic, climate, length of growing period (LPG) and soils for macro level and land use planning and effective transfer of agro - technology.
Agro Climatic Zones: - Agro climatic zone is a land unit in Irens of mator climate and growing period which is climatmenally suitable for a certain image of crops and cultivars (FAO 1983). An ecological region is characterized by district ecological responses to macro - climatic as expressed in vegetation and reflected fauna and equatic systems. Therefore an agro-ecological region is the land unit on the earth surface covered out of agro - climatic region, which it is super imposed on land form and the kinds of soils and soil conditions those act as modifiers of climate and LGP (Length of growing period).

With in a broad agro climatic region local conditions may result in several agro - ecosystems, each with it's own environmental conditions. However, similar agro ecosystems may develop on comparable soil, and landscape positions. Thus a small variation in climate may not result in different ecosystems, but a pronounced difference is seen when expressed in vegetation and reflected in soils. India has been divided into 24 agro - climatic zone by Krishnan and Mukhtar Sing, in 1972 by using "Thornthwait indices".

The planning commission, as a result of mid. term appairasal of planning targets of VII plan (1985 - 90) divided the country into 15 broad agro - climatic zones based on physiographic and climate. The emphasis was given on the development of resources and their optimum utilization in a suitable manner with in the frame work of resource constraints and potentials of each region. (Khanna 1989).

Agro climatic zones of India :- (Planning commission 1989)

1	Western Himalayan Region	Ladakh, Kashmir, Punjab, Jammu etc.brown soils & silty loam, steep slopes.
2	Eastern Himalayan Region	Arunachal Pradesh, Sikkim and Darjeeling. Manipur etc. High rainfall and high forest covers heavy soil erosion, Floods.

3	Lower Gangatic plants Regions	West Bengal Soils mostly alluvial & are prone to floods.
4	Middle Gangatic plans Region	Bihar, Uttar Pradesh, High rainfall 39% irrigation, cropping intensity 142%
5	Upper Gangatic Plains Region	North region of U.P. (32 dists) irrigated by canal & tube wells good ground water
6	Trans Gangatic plains Region	Punjab Haryana Union territory of Delhi, Highest sown area irrigated high
7	Eastern Plateaus & Hills Region	Chota Nagpur, Garhjat hills, M.P, W. Banghelkhand plateau, Orissa, soils Shallow to medium sloppy, undulating Irrigation tank & tube wells.
8	Central Plateau & hills Region	M. Pradesh
9	Western Plateau & hills Region	Sahyadry, M.S. M.P. Rainfall 904 mm Sown area 65% forest 11% irrigation 12.4%
10	Southern Plateau & Hills Region	T. Nadu, Andhra Pradesh, Karnataka, Typically semi and zone, Dry land Farming 81% Cropping Intensity 11%
11	East coast plains & hills Region	Tamil Nadu, Andhra Pradesh Orissa, Soils, alluvial, coastal sand, Irrigation
12	West coast plains & Hills Region	Sourashtra, Maharashtra, Goa, Karnataka, T. Nadu, Variety of cropping Pattern, rainfall & soil types.
13	Gujarat plains & Hills Region	Gujarat (19 dists) Low rainfall arid zone. Irrigation 32% well and tube wells.
14	Western Dry Region	Rajasthan (9 dists) Hot. Sandy desert rainfall erratic, high evaporation. Scanty vegetation, femine draughts.
15	The Island Region	Eastern Andaman, Nikobar, Western Laksh dweep. Typical equatorial, rainfall 3000 mm (9 months) forest zone undulating.

All crops cannot be grown in all types of agro climatic zones. Some crops can be possible to grow in all zones and some crops will be grown in some zones.

Every plant has its own agro-ecosystem.

Decision making in IPM requires an analysis of the ecosystem. Sampling and thresholds are important parts of that analysis. Some parts of the ecosystems interact. Now we will begin to use a method of Eco-system Analysis to facilitate discussion and decision making.

- First of all we have to take soil testing.
- Send it for analysis at local State Soil Testing Laboratory.
- According to the result we have to recommend the dose of organic and inorganic fertilizer.
- Selection of suitable seed variety
- Testing the seed viability
- Suggesting suitable seed treatment
- Raised nursery bed
- Preparation of compost
- Vermicompost preparation
- Preparation of rhizobium culture
- Blue green algae preparation
- Preparation of neem coated urea preparation

Agro Ecosystem Analysis (AESA) :

AESA is an approach which can be gainfully employed by extension functionaries and farmers to analyse field situations with regard to pests, defenders, soil conditions, plant health, the influence of climatic factors and their interrelationship for growing healthy crop. Such a critical analysis of the field situations will help in situations will help in taking appropriate decision on management practices.

A. The basic components of AESA are :

i. Plants health at different stages. Monitor symptoms of diseases and nematodes.

ii. Built-in-compensation abilities of the plants.

iii. Pest and defender population dynamics.

iv. Soil conditions.

v. Climatic factors.

vi. Farmers past experience.

B. The methodology of AESA is as under :

- . **Field Observations :**

i. Enter the field at least 5 ft. away from the bund. Select a site with a dimension of 1 sq mt. randomly.

ii. Record the visual obervation in following sequence:

a. Flying insects (both pests & defenders)

b. Close observation on pests and defenders which remain on the plants.

c. Observe pests like borer, BPH etc. and defenders like cooccinellid, chrysopa, ground beetle/rove beetle and earwigs etc, by scrapping the soil surface around the plants.

d. Record disease and its intensity.

e. Record insects damage and disease incidence in percentage.

iii. Record parameters like number of leaves, plant height and reproductive parts of the selected plants for makingobservation in the following weeks. Observe nematode damage symptoms.

iv. Record the types of weeds, their size and population density in relation to crop plant.

v. Record soil conditions viz flooded, wet or dry.

vi. Observe rodent live burrows.

vii. Record the climatic factors viz sunny, partially sunny, cloudy, rainy etc. for the preceding week.

C. Drawing :

First draw the plant at the centre on a chart. Then draw pests on left side and defender on the right side. Indicate the soil condition, weed population, rodent damage etc. Give natural colours to all the drawing, for instance, draw healthy plant with green colour, diseased plant/leaves with yellow colour. While drawing the pests and the defenders on the chart care should be taken to draw them at appropriate part of the plant, where they are seen at the time of observation. The common name of pest and alongwith diagram. The weather factor should bereflected in the chart by drawing the diagram of sun just above the plant if the attribute is sunny. If cloudy, the clouds may be drawn in place of sun. In case of partially sunny, the diagram of sun may be half masked with clouds.

D. Group Discussion and Decision making :

The observations recorded in the previous and current charts should be discussed among the farmers by raising questions relating to change in pest and defender population in relation to crop stages, soil condition, weather factors such as rainy, cloudy or sunny etc. The group may evolve a strategy based upon weekly AESA, ETL and corresponding change in P.D. ratio and take judicious decision for specific post management practices.

E. Strategy for decision making :

Some of the defenders like lady beetles, groundnut beetles, rove beetles, wasps play useful role in arriving at P.D. ratio.

F. AESA by Extension Functionaries :

The extension functionaries during their regular visit to the village mobilize the farmers, conduct AESA and critically analyse the various factors such as the pest population vis-a-vis defender population andtheir role in natural suppression of the pest, the influence of per prevailing weather condition/soil conditions on the likely build-up of defender/pest population. They may also take the decision based on the AESA which IPM components like release of defenders, application of need formulations/ safe pesticides are to be used for specific pest situation. Such an exercise may be repeated by the extension functionaries during every visit to the village and motivate the farmers to adopt AESA in their fields.

G. **AESA by Farmers :**

After a brief exposure during IPM demonstrations/ field trainings, farmers can practice AESA in their own field. Whenever trained farmers are available their experiences could be utilized in training their fellow farmers in their own villages. Thus a large group of farmers could be made proficiently competent in undertaking weekly AESA thereby empowering themselves in decision making on any specific pest situations. Farmers-to-farmers training approach will go a long way in practicing IPM on a large area on sustainable basis.

H. **Pest Monitoring Through Pheromones/ Light Traps etc.**

Certain pests required positioning of various kinds of traps like pheromones, light trap to monitor the initial pest build up. Therefore, the State Department of Agriculture is to initiate action for positioning of different kinds of traps at strategic locations at village level as per the following details.

1. **Pheromone trap –** 8 traps per ha. may be used to monitor stem borer moth population in Summer rice initiate in February to April (Boro & Early Ahu) trapping should be done from February to April and in Winter rice –(Sali rice), it should be done from July to September lures should be replaced at 10 days intervals.

2. **Light trap -** Chinsurah light trap or any other light trap with 200 watts mercury lamps can be operated for two hours in the evening to observe photo tropic insect pests. Traps should be placed away from other light sources.

3. **Sweep-nets-water pans** – Besides visual observations sweep-nets and water pans may also be used to assess the population of insect pests and bio-control agents.(In paddy crop) and mechanical collection and identification in vegetable crops.

I. Economic Threshold Level (ETL)

The Economic threshold level (ETL) is an attempt to improve decision making practices by using partial economic analysis on the impact of the control practice such as spraying a pesticide. At the ETL,the benefit of spraying a pesticide. At the ETL, the benefit of spraying is equal to the losses caused by the insects in the field. The farmers are advised to take appropriate control measures when the incidence crosses ETL. The ETL for some of the major pests are listed below:

Pest Economic Threshold Level

Tomato fruit borer One egg/one larve/one damaged fruit per plant

Whitefly 4 adults/leaf

(as a sucking pest)

Root-knot reniform Nematode 1-2 larvae/g soil

Objective:

The goal of the activity is to analyze the field situation by observation drawing and discussion. At the end of the activity, the group should have made a decision about any actions required in the field.

Time required = 120 minutes

Materials (per group)

One piece of note-book, paper one large size, drawing crayons or sketch pens.

Procedure:

1. Go to the field. Walk diagonally across the field and randomly choose 20 plants on the diagonal from. For each plant follow this examination process and record your observation. This should be done for each plot.

Insects : Then examine each plant from bottom to the top for hoppers, other insects. If many of the leaves are damaged by feeding look for caterpillars, *Epilachna* beetles and Shoot and fruit borer on leaves, fruits and tender shoots. Estimate the percent defoliation on the plant. Are larvae still present ? Collect the eggs and egg masses). Count the number of shoot damage and fruit damage. Record the number of all observation for the plant.

Disease : Notice the leaves and stems. Are there any discoloration due to disease (Ask the trainer if uncertain). Estimate the percent of leaf/stem area infected.

Record all observations.

Rats : Count the number of live burrows and observe for pieces of damaged fruit near the burrow.

Natural enemies : Count the each type of predator, and the number of larvae with parasites per plant.

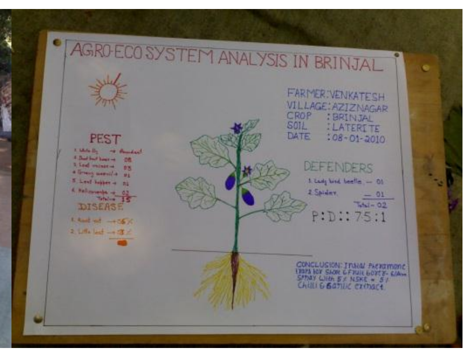
Plant: Find the shady place to sit as a group. Each group should sit together in a circle, with pencils, crayons data from each of the field activities (IPM), local package and other studies), and the drawing of the field ecosystem from the previous weeks.

2. Now make a drawing on the large piece of paper. Everyone should be involved in The drawing. Make a drawing for the each plot observed (IPM plot and local package). There are several rules for drawing which are as follows:

Draw plant with correct average number branches. Write the number branches on the plant somewhere. If the plant is healthy, color the plant as green. If the plant is diseased and lacking nutrients (or low in fertilizer) then color the plant or plant parts as brown or yellow.

Draw dead and dried leaves as yellow in color.

For weeds, draw approximate density and size of weeds in relation to the size of the plant. Draw the kind of weeds in the field (Broad leaf or grass type).



For pest population intensity, draw the insect pests as found in the field on the left side of the plant. Write the average number next to the insect. Also write the local name next to the insect. The data can also be summarized in a table on the right side.

For natural enemy population intensity, draw the predatory insects, other larval parasitoids and spiders as found in the field on the right side of the plant. Write the average number of the natural enemies and their local names next to the drawing.

For rats show the average number fruits/ plant or fruits cut by drawing the fruiting bodies laying near the burrow.

If the week was mostly sunny, add a sun. If the week was mostly sunny and cloudy together, draw a sun but half covered with dark clouds. If the week was cloudy all the day, for most of the week, put just dark clouds.

If the field was fertilized, then place a picture of a hand throwing N's, P's or K's into the field depending on the type of fertilizer used.

If insecticides were used in the field, show sprays with a nozzle and write the type of chemical coming out of the nozzle. If granules were broadcast, show a hand with the name of the pesticide being broadcast.

3. Keep your drawings for comparison for weeks later in the season.

4. Now discuss the questions listed for each stage of the plant depending on the crops observed. One person in the group is designated as the questioner (Change the person each week). This person will ask questions about the field. Write your answers on the paper and add a summary.

Each group should make a presentation of their field observation, drawing, discussion and summary. Different person should make the presentation each week.

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AGRO-ECOSYSTEM ANALYSIS METHODOLOGY IN VEGETABLE

Ecosystem analysis is the basic training method that helps farmers to understand their crop and to make decisions about their crop. Ideally, every weekly field school session should start with an Ecosystem Analysis by sub-groups, with group discussions afterwards. In this way, weekly development of the ecosystem can be followed, and weekly decision making can be practiced by the farmer.

AESA in vegetables will be taken in all three stages of the crop every weeks

Nursery Stage	- Observe all the nursery beds for insect pests and diseases
Vegetative Stage	- Observe 20 plants and scan entire plant for pests and bioagents -for sucking pests top two, middle two and bottom one leaves to be observe.
Flower and Fruiting Stage:	- Observe 20 plants and scan entire plant for live insect pests attack on flower buds, flower and fruit damage and healthy pests and available bioagents (all live ones) -for sucking pests top two, middle two and bottom one leaves to be observe.

Materials for each group of farmers:

- Note paper, pen
- Colour crayons
- Large piece of paper (about 60x80 cm.)

Activities:

1. Farmers form groups of four to five persons each. Some groups take the Farmers Practice field, and the other groups take the IPM field.

2. Each group sample 20 plants across the diagonal of the field. To select a plant, walk across the diagonal of the field and choose a plant at every 5 m. In large fields increase the distance between plants selected.

1. Then, select <u>three leaves</u> from the plant, one taken from the <u>top</u>, one from the <u>middle</u> and one from the <u>bottom</u> of the plant. Pick or turn the leaf and count the number of jassids, whitefly adults and nymphs, and aphids (ignore other sucking pests if not common).

4. Then, check all leaves and the stem systematically for any predators (starting from the top leaf downwards).

5. Then, count the total number of fruiting parts.

6. Then, open the bracts of each individual fruiting part and record:

    - Number of fruiting parts with fruit damage.
    - Number of fruit borer larvae.
    - Any predators.

7. Then, check on the ground surface under the plant and record any predators found.

8. Collect predators encountered in plastic vials to show to the other groups.

9. Uproot one brinjal or tomato or bhindi plant for drawing.

10. After 20 plants are sampled, find a place to sit as a group and make colour drawings on the large piece of paper. Draw the plant with the correct number branches. Draw the sun and indicates clouds if it is a cloudy day. Draw shedding buds in yellow. On the right hand side of the cotton plant, draw the pests found:

Sucking pests:

- Indicate the total number found (Top two leaves, Middle two leaves and bottom one leaves.

- And the total number of leaves checked (50 leaves).

(- calculate the average per leaf)

Fruit borer larvae :

- Indicate the total number of fruiting parts checked.
- Indicate the total number of fruiting parts with fruit borer damage.

(- calculate the percentage damaged fruiting parts).

On the left hand side of the cotton plant, draw the predators found. Again indicate the total numbers found (and calculate the average per plant). If weeds are common draw some weeds next to the vegetable plant. Indicate the intensity of disease incidence, rodent damage etc.

11. After drawing, discuss the following questions, for presentation.

Questions:

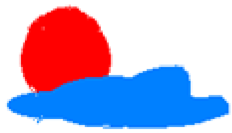
a) Describe the general condition of the plant.
b) What do farmers think are the most important factors affecting their crops at this stage ?
c) What, if any, measure should be taken ?

12. Then, when all groups have finalized their drawings and answered the questions, the groups should present their work in front of the other groups. They explain the sampling, explain the drawings and discuss the answers to the three questions.

13. One group for each treatment presents its results.

14. Each week, a different person of each group should do the presentation. In Farmers Field Schools, the Ecosystem analysis drawings of the previous weeks should be available for comparison and to discuss development of the crop and insects populations. It is easy to forget what the field looked like earlier in the season, what insect populations were found, and when control measures were taken.

AGRO ECO-SYSTEM ANALYSIS IN BRINJAL



General Observation
Village :
Farmer :
Variety :
Stage :

PEST

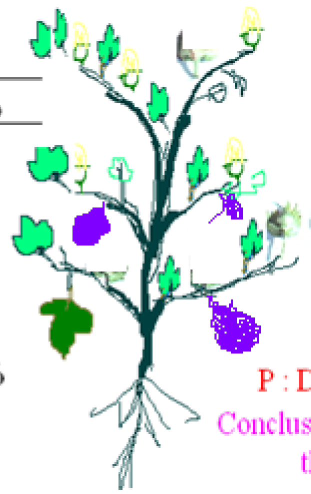
Aphids	- 10 %
Thrips	- 12
Jassids	- 10
White fly	- 20
Fruit borer	- 12
	54

DISEASES

Anthracnose 10%

WEEDS

RODENTS



DEFENDERS

Spiders	: 15
Dragonfles	: 10
Anthocorid	: 10
Geocorid	: 11
L.B.B.s	: 10
Chrysoperla sp.	: 20
Campolitis	: 5
	80

P : D Ratio 0.67 : 1

Conclusion : Since pest population is low there is no need for pesticidal spray

ECOLOGY & AGROECOSYSTEM CONCEPTS

Ecology is the scientific study of relationships in the natural world. It includes relationships between organisms and their physical environments (physiological ecology); between organisms of the same species (population ecology); between organisms of different species (community ecology); and between organisms and the fluxes of matter and energy through biological systems (ecosystem ecology).

"THE STUDY OF THE RELATIONSHIP BETWEEN AN ORGANISM AND ITS' ENVIRONMENT IS CALLED ECOLOGY"

Definitions of Ecology

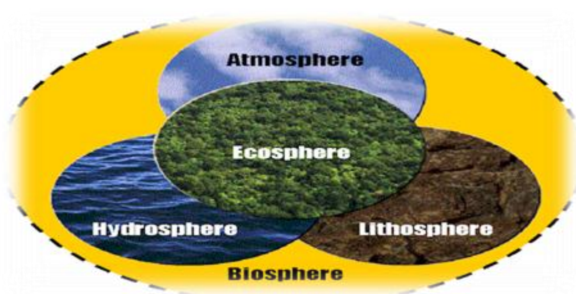
- ☐ 1866 Ernst Haeckel: the comprehensive science of the relationship of the organism to the environment
- ☐ 1927 Charles Elton: Scientific natural history
- ☐ 1963 E. P. Odum: The study of the structure and function of nature
- ☐ 1972 C. J. Krebs: The scientific study of the interactions that determine the distribution and abundance of organisms

Ecological spectrum

Biosphere, Landscape, Ecosystem, Community, Population, Organism, Organ system, Organ, Tissue, Cell, Sub cellular organelles, Molecules

Biosphere

- While the earth is huge, life is found in a very narrow layer, called the biosphere. If the earth could be shrunk to the size of an apple, the biosphere would be no thicker than the apple's skin.
- The biosphere, like the human body, is made up of systems that interact and are dependent on each other.



<u>Ecosystem</u>

- " ***Ecosystem is a Functionally independent unit in which there is an intricate & interdependent among the components***" *Ex: Pond, River, Forest, tree, desert.*
- All ecosystems must have a constant source of energy *(usually the sun)* and cycles. Examples are the water, nitrogen and carbon cycles.

- An ecosystem is made up of

1. Biotic or living
2. Abiotic or non-living components in a given area.

A biotic Factors

The *nonliving* things in an environment are called A BIOTIC factors. Examples of a biotic factors are

Sunlight , Temperature, Rainfall, Climate and Soil conditions.

Biotic Factors

Biotic factors are all the living things or their materials that directly or indirectly affect an organism in its environment. This would include organisms, their presence, parts, interaction, and wastes. In this type of classification, there are:

1.Autotrophs

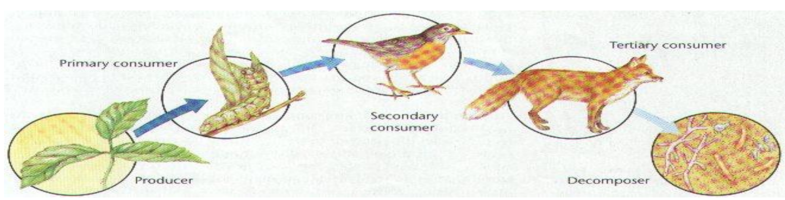
2. Heterotrophs

Organisms that produce their own food from an energy source, such as the sun, and inorganic compounds. Organisms that consume other organisms as a food source.

Food Chain

Food chains show which organisms eat other organisms

Grass → Rabbit → Fox →



- ✓ Producers - organisms which can make their own energy from carbon dioxide and water using sunlight for energy (plants)
- ✓ *Primary consumer* - organisms which eat producers (herbivores)
- ✓ *Secondary consumers* - organisms which eat primary consumers (carnivores)
- ✓ *Tertiary consumers* - organisms which eat secondary consumers (carnivores)

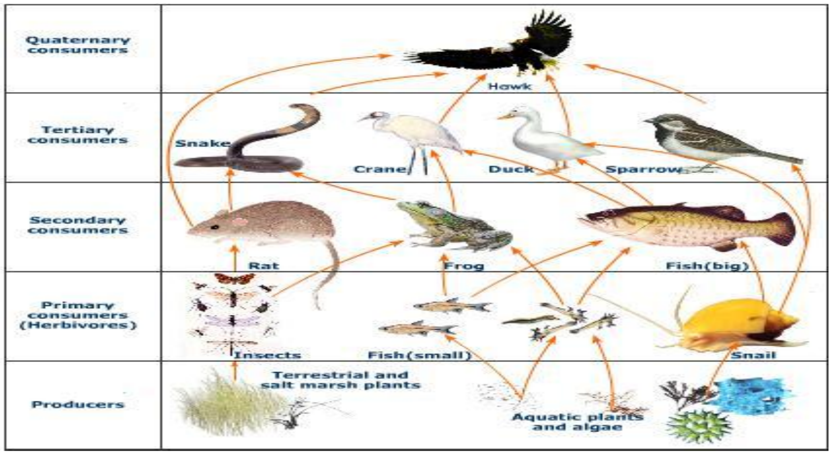
Each level of a food chain is known as a <u>trophic level</u> Food chains always start with a producer.

Producers are always on the first trophic level.

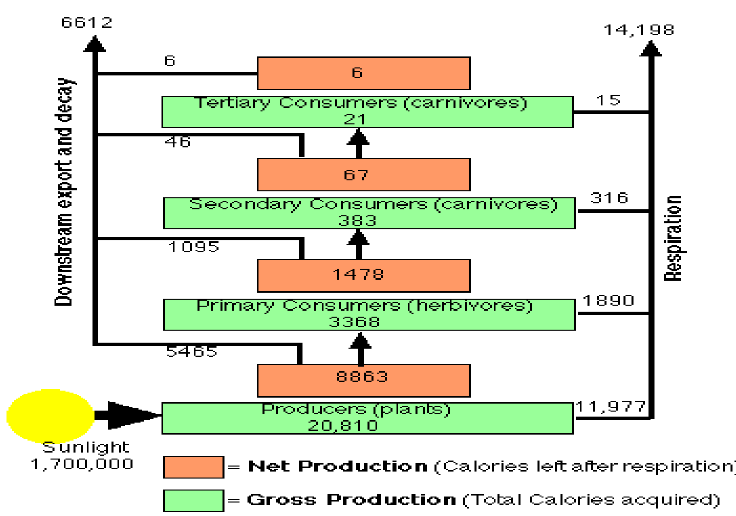
Tertiary consumer	Barn owl	Fourth trophic level
Secondary consumer	Wood mouse	Third trophic level
Primary consumer	Bark beetle	Second trophic level
Producer	Oak Tree	First trophic level

Food Webs

All the food chains in an area make up the food web of the area



Energy Flow Through Food Chains



Ecological pyramid

An ecological pyramid is a graphical representation designed to show the biomass or biomass productivity at each trophic level in a given ecosystem.

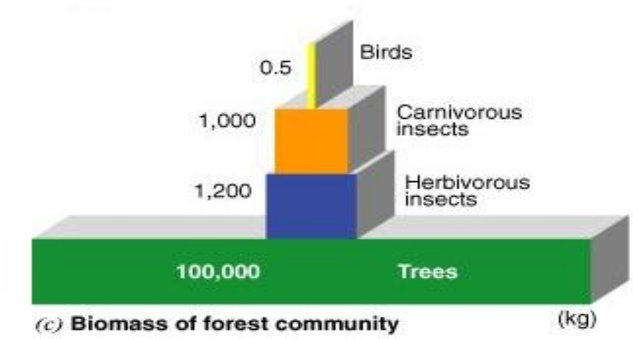
1 .Pyramid of biomass

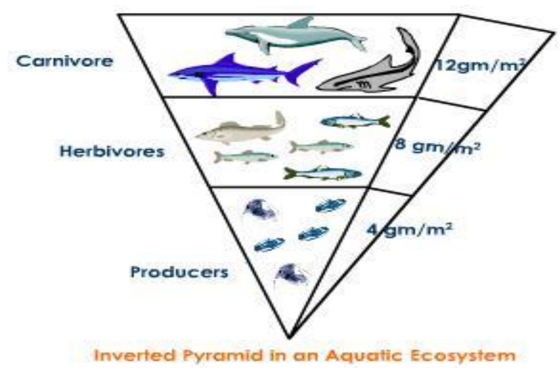
2 .Pyramid of Energy

3 .Pyramid of numbers

1 .Pyramid of biomass

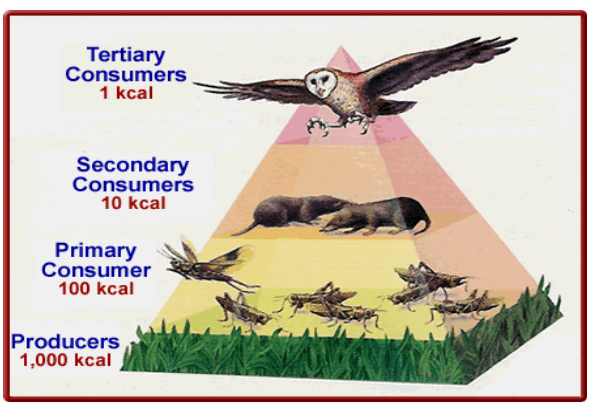
Typical units for a biomass pyramid could be grams per meter^2, or calories per meter^2.



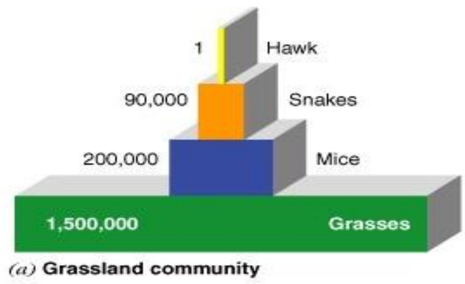


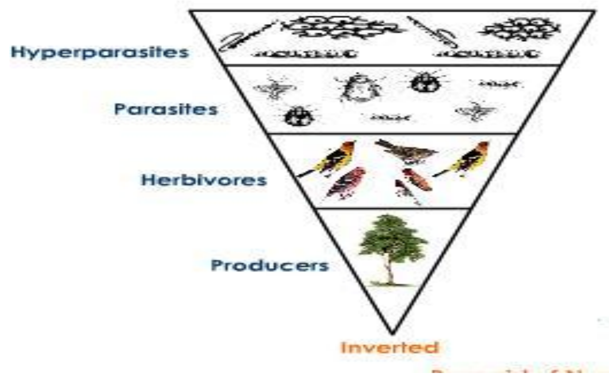
2 . Pyramid of Energy

Typical units would be grams per meter^2 per year or calories per meter^2 per year.



3. Pyramid of numbers





Population

All the organisms in an ecosystem that belong to the same species

Example - All the turtles in Town Lake

Community

A community is a group of interacting populations that occupy the same area at the same time

H**abitat**

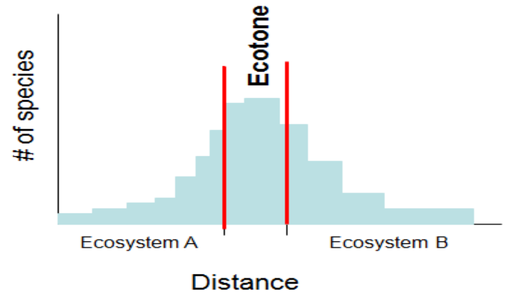
The place in which an organism lives .Provides the kinds of food and shelter, the temperature, and the amount of moisture the organism needs to survive.

Ecological Niche

A plant's or animal's ecological niche is a way of life that is unique to that species.

Niche and habitat are not the same. While many species may share a habitat, this is not true of a niche. Each plant and animal species is a member of a community. The niche describes the species' role or function within this community.

- **Ecotone** = transition zone between two ecosystems , Ecotones are often overlooked roads, fences, old fences, wind breaks.
- Ecotone (boundary) more diverse than either ecosystem
  numbers of species often greater in ecotone than in neighboring habitats.
- Edge effect
  in agroecosystem, edges of fields (near ecotone) often most diverse, highest number of species (natural enemies).



Biogeochemical Cycles

Nutrient circuits involving both biotic and abiotic components of ecosystems

Two categories:

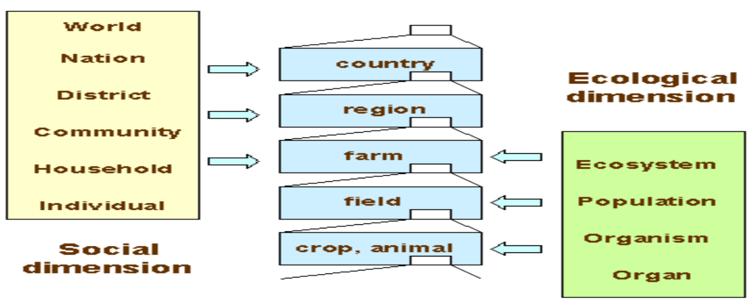
1.Gaseous cycles– Co2, N2,

2.Sedmentary -- Phosphorous, Sulpher

Agro-ecosystem

agro-ecosystems" to result from the manipulation of natural and biological resources by social groups.

Agro-ecosystems represent an integration of social and ecological systems, and can be considered from different disciplinary standpoints (social, economic, ecological) as well at several different levels of organization (crop, farm, community, watershed,etc).



System components

- ✓ different components of a system at any level is Agro-ecological "niches" (e.g. soil types, vegetation types, crops, woods, water sources, etc);

- ✓ Infrastructure (roads, wells, etc);
- ✓ Social units (different stakeholders, social groups, types of farmer, markets,etc).

- ✓ The instability of agroecosystems, which is manifested as the worsening of most insect pest problems, is increasingly linked to the expansion of crop onocultures at the expense of the natural vegetation, thereby decreasing local habitat diversity.
- ✓ Plant communities that are modified to meet the special needs of humans become subject to heavy pest damage and generally the more intensely such communities are modified, the more abundant and serious the pests.
- ✓ The inherent self-regulation characteristics of natural communities are lost when humans modify such communities through the shattering of the fragile thread of community interactions.
- ✓ Agroecologists maintain that this breakdown can be repaired by restoring
- ✓ the shattered elements of community homeostasis through the addition or enhancement of biodiversity.

Based on current ecological and agronomic theory, low pest potentials may be expected in agroecosystems that exhibit the following characteristics

1. High crop diversity through mixing crops in time and space.

2. Discontinuity of monocultures in time through rotations, use of short maturing varieties, use of crop-free or preferred host-free periods, etc.

3. Small, scattered fields creating a structural mosaic of adjoining crops and uncultivated land which potentially provide shelter and alternative food for natural enemies. Pests also may proliferate in these environments depending on plant species composition. However, the presence of low levels of pest populations and/or alternate hosts may be necessary to maintain natural enemies in the area

4. Farms with a dominant perennial crop component. Orchards are considered to be semi-permanent ecosystems, and more stable than annual cropping systems. Since orchards suffer less disturbance and are characterized by greater structural diversity, possibilities for the establishment of biological control agents are generally higher, especially if floral undergrowth diversity is encouraged.

5. High crop densities or the presence of tolerable levels of specific weed species.

6. High genetic diversity resulting from the use of variety mixtures or crop multilines

A key feature of annual cropping systems is the nature and frequency of soil disturbance regimes Periodic tillage and planting continually reverts the tilled area to an earlier stage of ecological succession. Physical disturbance of the soil caused by tillage and residue management is a crucial factor in determining soil biotic activity and species diversity in agroecosystems .

Tillage usually disturbs at least 15–25 cm of the soil surface and replaces stratified surface soil horizons with a tilled zone more homogeneous with respect to physical characteristics and residue distribution.

The loss of a stratified soil microhabitat causes a decrease in the density of species that inhabit agroecosystems.

One gram of soil may contain over a thousand fungal hyphae and up to a million or more individual bacterial colonies. Energy, carbon, nitrogen and other nutrient fluxes through the soil decomposing subsystem are dominated by fungi and bacteria, although invertebrates play a certain role in N flux.

	Nutrient Cycling	Soil Structure
Microflora (fungi, bacteria, actino-mycetes)	Catabolize organic matter; mineralize and immobilize nutrients	Produce organic compounds that bind aggregates; hyphae entangle particles onto aggregates
Microfauna (Acarina, Collembola)	Regulate bacterial and fungal populations; alter nutrient turnover	May affect aggregate structure through interactions with microflora
Mesofauna (Acarina, Collembola, enchytraeids)	Regulate fungal and microfaunal populations; alter nutrient turnover; fragment plant residues	Produce fecal pellets; create biopores; promote humification
Macrofauna (isopods, centipedes, millipedes, earthworms, etc.)	Fragment plant residues; stimulate microbial activity	Mix organic and mineral particles; redistribute organic matter and micro-organisms; create biopores; promote humification; produce fecal pellets

biodiversity in agroecosystems

Modern agriculture implies the simplification of the structure of the environment over vast areas, replacing nature's diversity with a small number of cultivated plants and domesticated animals

In fact, the world's agricultural landscapes are planted mostly with some 12 species of grain crops, 23 vegetable crop species, and about 35 fruit and nut crop species.

more than 70 plant species spread over approximately 1440 million ha of presently cultivated land in the world.

Genetically, modern agriculture is shockingly dependent on a handful of varieties for its major crops. For example, in the US, 60–70% of the total bean area is planted with 2–3 bean varieties, 72% of the potato area with four varieties and 53% of the cotton area with three varieties

In contrast, biodiversity is not foreign to traditional farmers in the Third World. In fact, a salient feature of traditional farming systems is their degree of plant diversity in the form of polycultures and/or agroforestry patterns.

In fact the species richness of all biotic components of traditional agroecosystems is comparable with that of many natural ecosystems.

Traditional, multiple cropping systems are estimated to still provide as much as 15–20% of the world's food supply.

In general, the degree of biodiversity in agroecosystems depends on four main characteristics of the agroecosystem

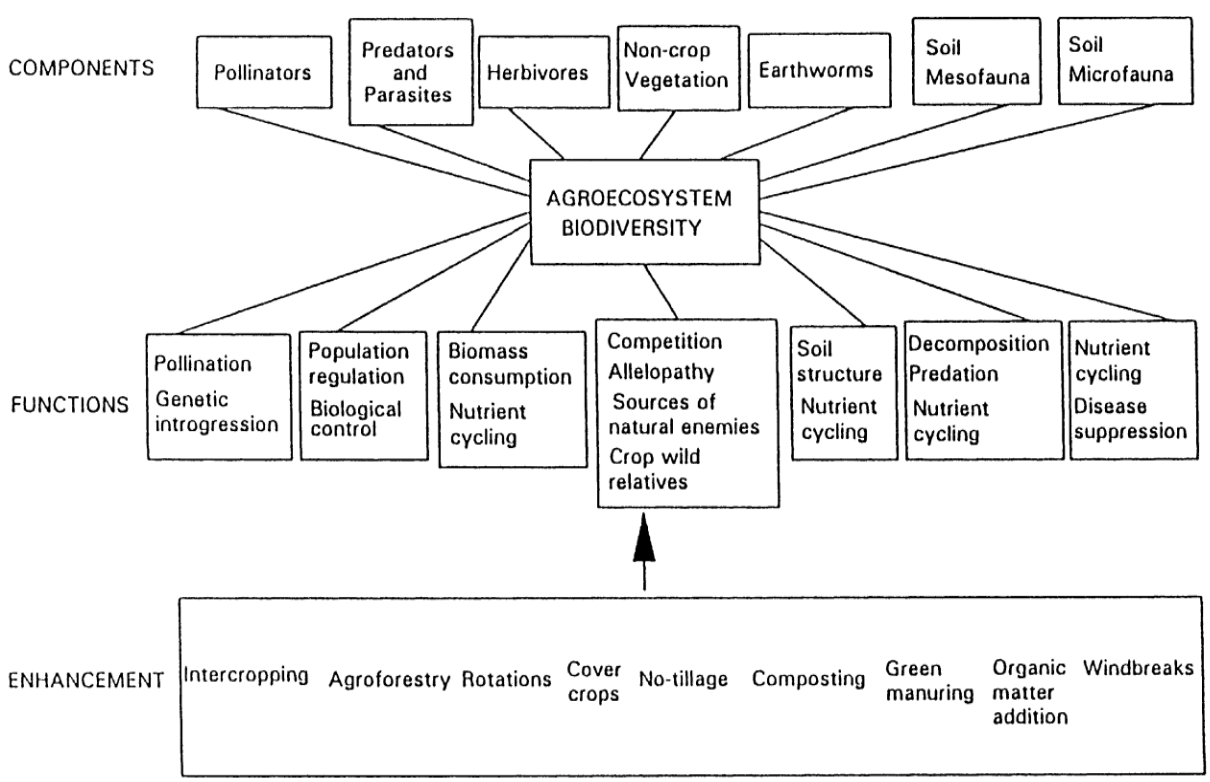
1. The diversity of vegetation within and around the agroecosystem.
2. The permanence of the various crops within the agroecosystem.
3. The intensity of management.
4. The extent of the isolation of the agroecosystem from natural vegetation.

The biodiversity components of agroecosystems can be classified in relation to the role they play in the functioning of cropping systems According to this, agricultural biodiversity can be grouped as follows.

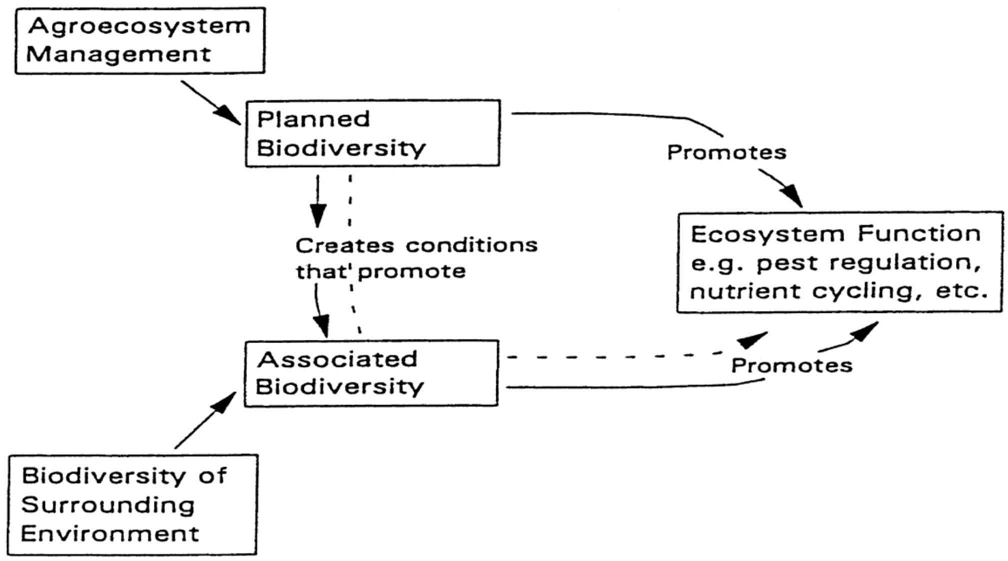
Productive biota: crops, trees and animals chosen by farmers which play a determining role in the diversity and complexity of the agroecosystem.

Resource biota: organisms that contribute to productivity through pollination, biological control, decomposition, etc.

Destructive biota: weeds, insect pests, microbial pathogens, etc. which farmers aim at reducing through cultural management



The components, functions, and enhancement strategies of biodiversity in agroecosystems



The relationship between planned biodiversity and associated and how the two promote ecosystem function

Agroecology provides basic ecological principles on how to study, design and manage agroecosystems that are productive, enduring and natural resource conserving. Agroecosystems can be manipulated to improve production andproduce more sustainably, with fewer negative environmental and social impacts and fewer external inputs. The design of such systems is based on the application of the following ecological principles

1. Enhance recycling of biomass and optimizing nutrient availability and balancing nutrient flow.

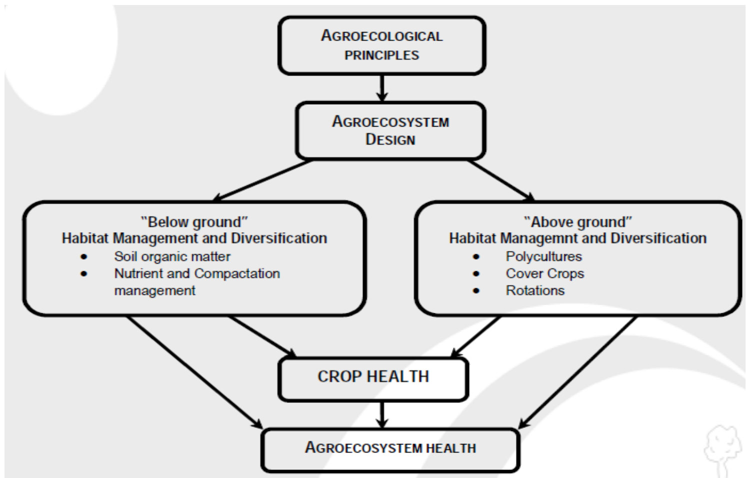
2. Securing favorable soil conditions for plant growth, particularly by managing organic matter and enhancing soil biotic activity.

3. Minimizing losses due to flows of solar radiation, air and water by way of microclimate management, water harvesting and soil management through increased soil cover.

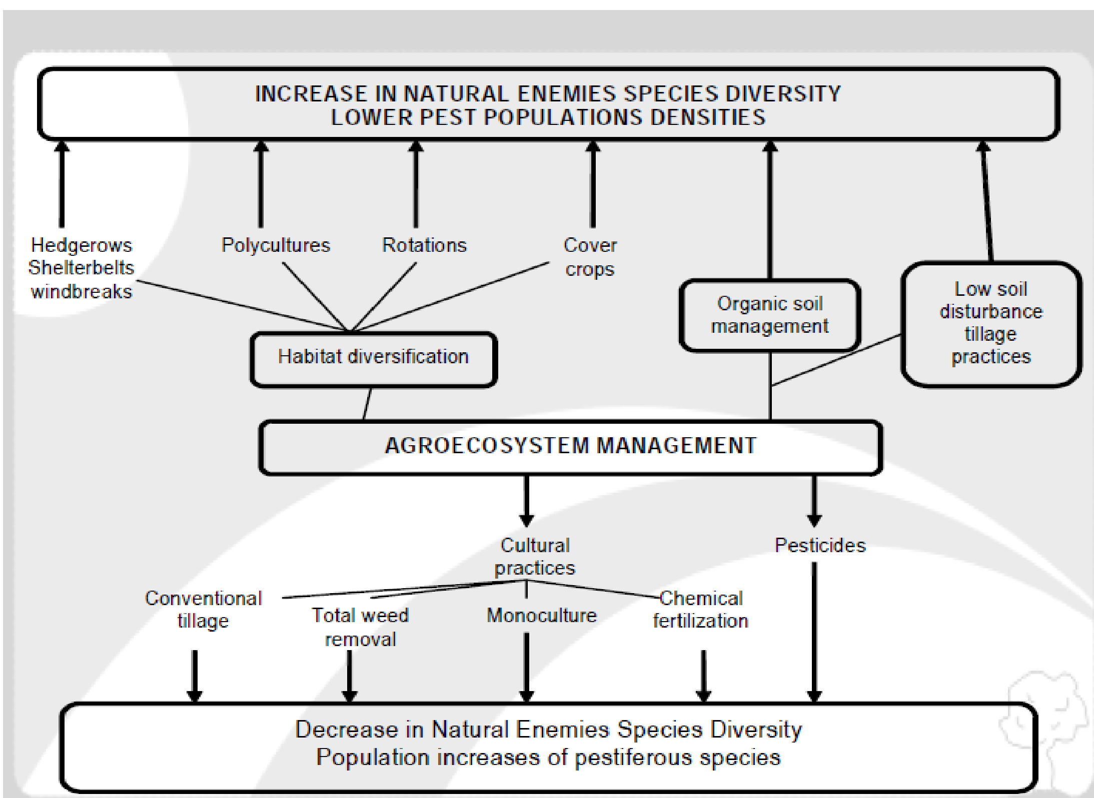
4. Species and genetic diversification of the agroecosystem in time and space.

5. Enhance beneficial biological interactions and synergisms among agrobiodiversity components thus resulting in the promotion of key ecological processes and services.

These principles can be applied by way of various techniques and strategies



Summary of how agro ecosystem design may affect the health of crops and the agro ecosystem.



The effects of agroecosystem management and associated cultural practices on the diversity of natural enemies and the abundance of insect pests.

In india there are several classifications of agro-climatic regions and soils proposed by several agencies. The reader is advised to study the earlier booklets on the related topics "Land Capability Classification" Booklet No.518 and " Agro-climatic Divisions of India" Booklet No.521. This booklet is on the agro-ecological regions of India; but there may be several things similar to the Booklet on Agro-climatic Divisions of India.

Planning Commission as part of the mid-term appraisal of the planning targets of VII Plan (1985-1990) divided the country into 15 broad agro-climatic zones based on physiography and climate. They are the following

1. Western Himalayan Region, 2. Eastern Himalayan I Region, 3. Lower Gangetic Plains Region, 4. Middle Gangetic Plains Region, 5. Upper Gangetic Plains Region, 6. Trans-Gangetic Plains Region, 7. Eastern Plateau & Hills Region, I 8. Central Plateau and Hills Region, 9. Western Plateau and Hills Region,10. Southern Plateau and Hills Region, 11. East Coast Plains and Hills Region, 12. West Coast plains & Hills Region, 13. Gujarat Plains & Hills Region, 14. Western Dry Region and 15. The Island Region.

ECOSYSTEM SERVICES AND THEIR SIGNIFICANCE

Rivers, streams and wetlands provide people with a wide range of benefits often referred to as "Ecosystem Services"

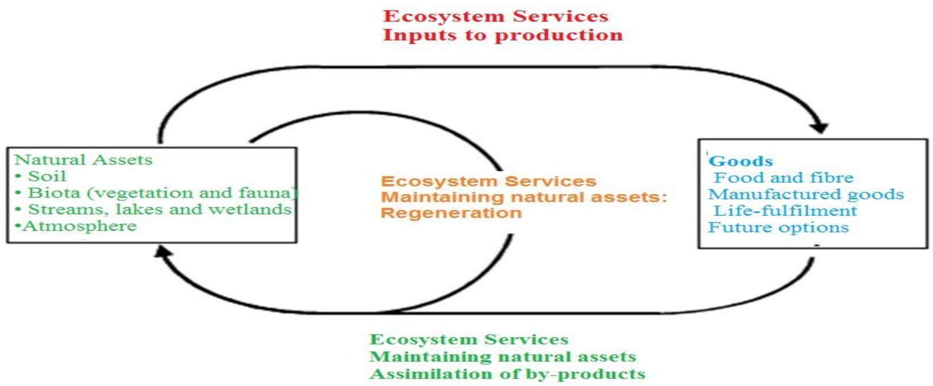
Ecosystem Services Approach

Provides a frame work by which ecosystem services are integrated into public and private decision making.

Its implementation typically incorporates a variety of methods includes

1. Ecosystem service dependency and impact assessment
2. Valuation
3. Scenarios

policies and other interventions targeted at sustaining ecosystem services



1)Transformations of natural assets into products valued economically

(2) Transformations of the by-products - ecosystem services back into natural assets

(3) internal transformations among natural assets to maintain those assets

Ecosystem services into four broad categories:

1. Provisioning services - the goods or products obtained from ecosystems

2. Regulating services - the benefits obtained from an ecosystem's control of natural processes

3. Cultural services - the nonmaterial benefits people obtain from ecosystem services

4. Supporting services - the underlying processes that are necessary for the production of all other ecosystem services

1. ***Provisioning services - the goods or products obtained from ecosystems***

Service	Sub-category	Definition	Examples
Food	Crops	Cultivated plants or agricultural produce which are harvested by people for human or animal consumption	Grains Vegetables Fruits
	Livestock	Animals raised for domestic or commercial consumption or use	Chicken Pigs Cattle
	Capture fisheries	Wild fish captured through trawling and other non-farming methods	Cod Shrimp Tuna
	Aquaculture	Fish, shellfish, and/or plants that are bred and reared in ponds	Clams Oysters Salmon
	Wild foods	Edible plant and animal species gathered or captured in the wild	Fruits and nuts Fungi Bush meat
Fiber	Timber and wood fibers	Products made from trees harvested from natural forest ecosystems, plantations, or non-forested lands	Industrial round wood Wood pulp Paper
	Other fibers (e.g., cotton, hemp,	Non-wood and non-fuel based fibers extracted from the natural environment for a variety of uses	Textiles Cordage (twine, rope)

	silk)		
Biomass fuel		Biological material derived from living or recently living organisms –both plant and animal – that serves as a source of energy	Fuel wood, Grain for thanol production, Dung
Freshwater		Inland bodies of water, groundwater, rainwater, and surface waters for household, industrial, and agricultural uses	Freshwater for drinking, cleaning,
Genetic resources		Genes and genetic information used for animal breeding, plant improvement, and biotechnology	Genes used to increase crop Resistance
Biochemicals, natural medicines, and pharmaceuticals		Medicines, biocides, food additives, and other biological materials derived from ecosystems for commercial or domestic use	cancer drugs, Tree extracts used for pest control

2. Regulating services - the benefits obtained from an ecosystem's control of natural processes

Air quality regulation		Influence ecosystems have on air quality by emitting chemicals to the atmosphere or extracting chemicals from the atmosphere	Lakes serve as a sink for industrial emissions of sulfur Compounds
Climate regulat	Glob	Influence ecosystems have on the global climate by emitting greenhouse gases or aerosols to	Forests capture and store carbon dioxide , Cattle and rice paddies emit

ion	al	the atmosphere	methane
	Regional and local	Influence ecosystems have on local or regional temperature, precipitation and other climatic factors	Forests can impact regional rainfall levels
Water regulation		Influence ecosystems have on the timing and magnitude of water runoff, flooding, and aquifer recharge	Permeable soil facilitates,
Erosion regulation		Role vegetative cover plays in soil retention	Vegetation such as grass and trees prevents soil loss
Water purification and waste treatment		Role ecosystems play in the filtration and decomposition of organic wastes and pollutants in water	Soil microbes degrade organic waste rendering it less harmful

Water purification and waste treatment	Role ecosystems play in the filtration and decomposition of organic wastes and pollutants in water	Soil microbes degrade organic waste rendering it less harmful
Disease regulation	Influence that ecosystems have on the incidence and abundance of human pathogens	standing water, a breeding area for mosquitoes
Pest regulation	Influence ecosystems have on the prevalence of crop and livestock pests and diseases	Predators from nearby forest, such as bats, toads, snakes
Pollination	Animal-assisted pollen transfer between plants, without which many plants cannot reproduce	Bees from nearby forests pollinate crops

3. Cultural services - the nonmaterial benefits people obtain from ecosystem services

Service	**Definition**	**Examples**
Ethical values	Spiritual, religious, aesthetic, intrinsic or other values people attach to ecosystems, landscapes, or species	Spiritual fulfillment derived from sacred lands and rivers
Existence values	The value that individuals place on knowing that a resource exists, even if they never use that resource.	Belief that all species are worth protecting regardless of their utility to human beings

Recreation and ecotourism	Recreational pleasure people derive from natural or cultivated ecosystems	Hiking, camping and bird Watching Going on safari

4. Supporting services - the underlying processes that are necessary for the production of all other ecosystem services

Service	Definition
Nutrient cycling	Process by which nutrients – such as phosphorus, sulfur and nitrogen – are extracted from their mineral, aquatic, or atmospheric sources or recycle from their organic forms and ultimately return to the atmosphere, water, or soil
Soil formation	Soil formation Process by which organic material is decomposed to form soil
Primary production	Formation of biological material through assimilation or accumulation of energy and nutrients by organisms
Photosynthesis	Process by which carbon dioxide, water, and sunlight combine to form sugar and oxygen
Water cycling	Flow of water through ecosystems in its solid, liquid, or gaseous forms

what are the ecosystem services that are essential for agriculture?

(a) Pollination

- Pollination is another important ecosystem service to agriculture that is provided by natural habitats in agricultural landscapes.
- Approximately 65 per cent of plant species require pollination by animals, & an analysis of data from 200 countries indicated that 75 % of crop species of global significance for food production rely on animal pollination, primarily by insects.
- Only 35–40% of the total volume of food crop production comes from animal-pollinated crops, however, since cereal crops typically do not depend on animal pollination.

(b)Ecosystem services flowing to agriculture

- The production of agricultural goods is highly dependent on the services provided by neighbouring natural ecosystems,

Biological pest control

- Biological control of pest insects in agro ecosystems is an important ecosystem service that is often supported by natural ecosystems.
- Non-crop habitats provide the habitat and diverse food resources required for arthropod predators and parasitoids, insectivorous birds and bats, and microbial pathogens that act as natural enemies to agricultural pests and provide biological control services in agroecosystems.

These biological control services can reduce populations of pests, thereby reducing the need for pesticides

(c) Water quantity and quality

- The provision of sufficient quantities of clean water is an essential ecological service provided to agroecosystems, and agriculture accounts for about 70 per cent of global water use (FAO 2003).
- Perennial vegetation in natural ecosystems such as forests can regulate the capture, infiltration, retention and flow of water across the landscape.
- The plant community plays a central role in regulating water flow by retaining soil, modifying soil structure and producing litter.

(d) Soil structure and fertility

- Soil structure and fertility provide essential ecosystem services to agroecosystems (Zhang et al. 2007).
- Well-aerated soils with abundant organic matter are fundamental to nutrient by crops, as well as water retention.
- Soil pore structure, soil aggregation and decomposition of organic matter are influenced by the activities of bacteria, fungi and macro fauna, such as earthworms, termites and other invertebrates.

Micro-organisms mediate nutrient availability through decomposition of detritus and plant residues and through nitrogen fixation

(e) Landscape influences on the delivery of ecosystem services to agriculture

- The delivery of ecosystem services to agriculture is highly dependent on the structure of the landscape in which the agroecosystem is embedded.
- Agricultural landscapes span a succession from structurally simple landscapes dominated by one or two cropping systems to complex mosaics of diverse cropping systems embedded in a natural habitat matrix .

- In complex landscapes, natural enemies and pollinators move among natural and semi-natural habitats that provide them with resources that may be scarce in crop fields.

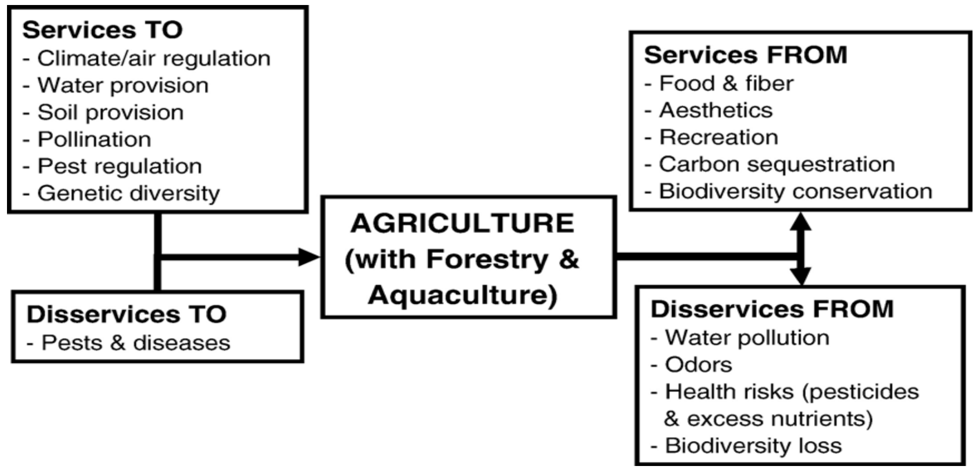
Ecosystem disservices from agriculture

- (a) Agriculture can also be a source of disservices, including loss of biodiversity, agrochemical contamination and sedimentation of waterways, pesticide poisoning of non - target organisms, and emissions of greenhouse gases and pollutants.
- Nutrient cycling and pollution- From the local scale to the global scale, agriculture has profound effects on biogeochemical cycles and nutrient availability in ecosystems.
- The two nutrients that most limit biological production in natural and agricultural ecosystems are nitrogen and phosphorus, and they are also heavily applied in agroecosystems.
- Nitrogen and phosphorus fertilizers have greatly increased the amount of new nitrogen and phosphorus in the biosphere and have had complex, often harmful, effects on natural ecosystems
- The anthropogenically mobilized nutrients have entered both groundwater and surface waters, resulting in many negative consequences for human health and the environment.
- Approximately 20 per cent of N fertilizer applied in agricultural systems moves intoaquatic ecosystems (Galloway et al. 2004).
- Impacts of nutrient loss from agroecosystems include groundwater pollution and increased nitrate levels in drinking water, eutrophication, increased frequencyand severity of algal blooms,.
- Agricultural intensification in the landscape can diminish other ecosystem services as well. Protection of groundwater and surface water quality can be threatened by intensification because of increased nutrients, agrochemicals and dissolved salts.
- Other ecosystem disservices from agriculture include applications of pesticides that result in loss of biodiversity.
- pesticide residues in surface and groundwater, which degrades the water provisioning services provided by agroecosystems.
- Emissions of greenhouse gases Agricultural activities are estimated to be responsible for 12–14% of global anthropogenic emissions of greenhouse gases.
- Conversion of natural ecosystems to agriculture reduces the soil carbon pool by 30–50% over 50–100 years in temperate regions and 50–75% over 20–50 years in the tropics

Ecosystem services from agriculture

- On-farm management practices can significantly enhance the ecosystem services provided by agriculture.
- Habitat management within the agroecosystem can provide the resources necessary for pollinators or natural enemies.
- Many studies have identified the important role of perennial vegetation in supporting biodiversity in general and beneficial organisms in particular.
- Agriculture (including planted forests) conventionally supplies food, fiber, and fuel—"provisioning services" in Ecosystem Services

Ecosystem services to and from Agriculture



Concepts of Biosecurity

INTRODUCTION:

Since the dawn of civilization, man utilized his best possible efforts to domesticate the bounty of nature as per his needs. It is not just in recent years that the countries are being invaded by alien species, since time immemorial, man started to move the plants and animals wherever he fancied. In a way it paved way for species richness in newer area and domestication has become part of human settlement. It is not true that all alien species are harmful or dangerous, even the invasive species are not so dangerous in their place of origin, as the invasiveness is curtailed due to influence of many factors of the particular ecosystem. The alien species become invasive in newer area due to absence of natural enemies and congenial environmental parameters. Some alien species became beneficial and some became nuisance. In the past scores of plants and animals have been exchanged, moved or introduced to newer horizons due to human aided activities. The introduction of localized species to cross the physical boundaries is made possible only by means of human interference. For example, the first record of **coffee** growing in India is traced back to 1670 in the hills of Chikmagalur, Karnataka and supposed to be introduced from Yemen (Widipedia). **Potato** was introduced to Europe from Andes (South America) by the Spanish in second half of 16^{th} century and Potato was introduced into India in the early 17^{th} century, most likely aboard Portugal ships, and presently a third of world production of potato is harvested in India and China (FAOSTAT). Similarly **Chilli** was introduced into India from Mexico during 15^{th} century and it has become the integral part of Indian culinary. India is the leading producer of Chilli in the world. In India, commercial cultivation of natural **Rubber** was introduced by the British planters, although the experimental efforts to grow rubber on a commercial scale in India were initiated as early as 1873 at the Botanical Gardens, Calcutta, the first commercial *Hevea* plantations in India were established at Thattekadu in Kerala in 1902. In the 19th and early 20th century, it was often called "India rubber." Vice-a-verse, there are lots of such economically valuable plant species which originated in India is now spread to all over the world. To site a few examples: Black pepper, Tea, Cardamom, Coconut, Neem, Mango etc.

Effect of Invasive species:

Though the countries have benefitted from exchange or intentional / unintentional introduction of new species, it has not always ended up with beneficial results. History is rich with tales of the disastrous outcomes of some intentional introductions. Further careless behavior by man leads to unintentional introductions, the so-called ‘accidents’ now account for the majority of disastrous invasions. The following are few of such catastrophes of introduced invasive alien species around the globe:

- **Great Famine of Irish**: Potato was introduced into Ireland as a garden crop and during late 17^{th} century it was consumed as supplementary food. By early 18^{th} century, it assumed the status of staple food for the poor during winter season and as well considered as agrarian economy as it fetched more money and hence grown in more acreage (<60%). In 1843-44, a new disease started to destroy the crops and was identified as late blight of potato, *Phytophthora infestans.* Late blight of potato infection completely destroyed potato crop in 1845, which lead to the starvation and death of 1 million people and migration of another 1 million from Ireland between 1845 to 1852. The unfortunate event of late blight devastation occurred due to incursion of *Phytophthora infestans* from USA, which caused loss of around £3,500,000 potatoes.
- **Toppling of Grapevine industry in Europe**: Classical example of transboundary movement of plant pests is the introduction of Powdery mildew (*Oidium tuckeri*) into Europe with American grape-vines. Its pathogenecity on European grape vine was unknown at that time and the disease spread like wild fire on European grape vines (1850). To control powdery mildew, root-stocks of resistant varieties were imported from America (1854). However, these grape vines carried *Phylloxera vastatrix*, a root inhabiting aphid of grape vines. To combat this pest, more American vines resistant to Phylloxera were introduced, but these additional introductions brought with them the downy mildew (*Plasmopara viticola*), and black rot (*Guignardia bidwellii*). In France, where the vine industry was thriving, had to face the burnt of these pest incursions and many business men abandoned vine production and emigrated to Algeria and other countries. Further, these incidences lead to the formulation of Bordeaux mixture pesticide.
- **Colossal toad menace**: The cane toad, *Bufo marinus*, (Giant neotropical toad), native of central and south America, was introduced into Australia by the sugarcane industry to control two pests, the grey backed cane beetle (*Dermolepida albohirtum*) and frenchie beetle (*Lepidiota frenchi*). 101 toads were imported in June1935 and within 6 months the population exploded to 60000 and was released in the cane fields. Initially, the bio-control agent was so successful, whereas it became a environmental menace in a short period of time, causing ecological imbalance replacing the native frogs due to its over

population, further, it became the reason for extinction of snake and fox species due to consumption of this poisonous toad. Even the tadpoles are poisonous.

- **Green Cancer of Tahiti**: The prolific tree *Miconia calvescens* has overrun Tahiti's native forests. Miconia is one of the most destructive invaders in tropical rain forest habitats. It is a serious threat to ecosystems in the Pacific because of its ability to invade intact native forests. Miconia has earned itself the descriptions such as the 'green cancer of Tahiti' and the 'purple plague of Hawaii'. Once miconia is established at a certain place it drastically changes the ecosystem and biodiversity of that environment.
- **Food turned foe**: Philippine rice farmers have lost nearly US$1 billion in crops to the invasive golden apple snail, *Pomacea canalicualata* which was originally introduced from South America to south-east Asia around 1980, as a local food resource and as a potential gourmet export item. The markets never developed; the snails escaped or were released, and became a serious pest of rice.
- **Water weeds**: African nations spend an estimated US$60 million annually on the control of alien water weeds, like water hyacinth *Eichhornia crassipes* and water lettuce *Pistia stratiotes*.
- **Fang's of greed:** Brown snake (*Boiga irregularis*) was accidentally introduced into Guam. The brown snake decimated Guam's local bird species and herpatofauna, causing extinction of half of native birds and lizard species and 2/3rd of bat species. By eliminating the pollinators, the brown snake invasion has caused a cascading effect on Guam's ecosystems, reducing pollination by lizards and birds and reducing plant regeneration and coverage as a consequence.
- **Malaria menace**: Avian malaria, through its mosquito vector has contributed to the extinction of at least 10 native bird species in Hawaii and threatens many more.

The potential dangers imposed by invasive species on plant, animal and human health and the ecological and environmental impacts exerted all over the globe, has created awareness on preserving the natural flora and fauna of a nation, and at the same time to promote safe trade, the need for global level coordination in harmonizing the sanitary and phytosanitary measures (SPS) was initiated through WTO-SPS agreements. The SPS measures are operated through standard setting bodies such as IPPC (International Plant Protection Convention), Rome for plant health, OIE (Office international des epizooties) for animal health and CAC (Codex Alimentarius Committee) for human health related issues at international level. FAO (Food and Agriculture Organization) has realized the potent threat of bioinvasion and bioterrorism and introduced the new concept of 'Biosecurity' within the ambience of safeguarding the biodiversity of a nation.

The exponential expansion of trade in agricultural material and the speed at which the agricultural products are moving around the globe, coupled with the removal of trade restrictions in post-WTO era, the chance of pests, diseases and harmful organisms to move to hitherto unrecorded areas are high. It is very natural for the associated pests to trod around the globe along with plant products to newer areas, but the unnatural events of record of invasive alien species in the recent times owing to the human interference is happening at an higher scale than the pest can move around from its place of origin on its own. In the fast phased developments in international trade and tourism, there is an increased risk of introduction of exotic pests into the country. On the other hand, the threats posed by introduction of Living Modified Organisms (LMO) and the effects of GMO on human, animal and plant health are unknown. Bio-terrorism and biological warfares are the major emerging threats at international level, which can dismantle the entire nation's economy, growth and loss of lives. Apart from all these visible dangers, transboundary diseases of virulent strains of pathogens of human, animal and plant health poses greater threat to health, food and economy. It is because of these vulnerable factors that agricultural biosecurity has emerged as an urgent issue, which requires implementation of regulations, policies, enhancement of technological capabilities and human capacity building to meet such threats.

National regulatory and export certification systems are being challenged by large increases in the volume of food and agricultural products being traded internationally, by the expanding variety of imported products and by the growing number of countries from which these imports are originating. Increased travel is also creating more pathways to spread pests, diseases and other hazards that are moving faster and further than ever before. Improved coordination is being sought among national bodies responsible for enforcing sanitary, phytosanitary and zoosanitary measures to better protect human, animal and plant life and health without creating unnecessary technical barriers to trade. There is an urgent need to protect the biosecurity of a nation from the bio-invaders to sustain food security and preserve biodiversity. 'Biosecurity' is a relatively a new concept and a term that is evolving as usage varies from country to country with different specialist groups using in different ways.

NEED FOR AGRICULTURAL BIOSECURITY AT GLOBAL AND NATIONAL LEVEL:

The world has truly become a global village with reference to communication and transport. The globalization of trade and disappearance of tariff barriers in trade has opened flood-gates of alien species to move around the world at a faster rate and speed. This really poses greater implications in the context of agricultural biosecurity of a nation. The later part of WTO regime is witnessing mass invasion of pests into newer areas, causing devastations and unbalancing the economy of many nations. Developing and underdeveloped countries are the most affected in the absence of preparedness to combat the invasion. The latest report of **Cotton mealy bug** (*Phenococcus solenopsis*), native of USA into Pakistan and India are major concern to the sub-continent. India, being a lead producer of cotton with more than 60 million people dependent on cotton farming is worst affected since its report in 2005. The cotton mealy bug is reported in all the states of cotton belt. Similarly introduction of **Papaya mealy bug** (*Paracoccus marginatus*) into India (2008) is a growing concern, which is likely to cripple the export potential of papaya. The transboundary movements of pathogens are posing major threats to plant, animal and human health. The incursions of Avian influenza virus, Swine flu, SARS etc., also reinstates the urgent need to strengthen biosecurity of our nation. The ISSG (Invasive Species Specialist Group) of IUCN (International Union for Conservation of Nature) has identified **100 of the World's Worst Invasive Alien Species**, which includes plants, animals and pests. From the identified list, unfortunately **12 invasive species** of plants and plant pests have invaded into India. Such as:

- Banana bunchy top virus
- Phytophthora root rot (*Phytophthora cinnamomi*)
- Water hyacinth (*Eichhornia crassipes*)
- Black wattle (*Acacia mearnsii*)
- Gorse (*Ulex europaeus*)
- Lantana (*Lantana camara*)

- Mile-a-minute weed (*Mikania micrantha*)
- Mimosa (*Mimosa pigra*)
- Siam weed (*Chromolaena odorata*)
- Crazy ant (*Anoplolepis gracilipes*)
- Sweet potato whitefly (*Bemisia tabaci*)
- Giant African snail (*Achatina fulica*)

DEFINITIONS:

'***Biosecurity***' broadly describes the process and objective of managing biological risks associated with food and agriculture in a holistic manner (FAO).

'***Biosecurity***' is a strategic and integrated approach consisting of policy and regulatory frameworks to analyze and manage risks to human, animal and plant life and health, and associated risks to the environment.

'***Biosecurity***' is a balancing act between a nation and people and encouraging tourism and international trade that are vital to a nation's economy.

'Biosecurity' covers the introduction of plant pests, animal pests and diseases, and zoonoses, the introduction and release of genetically modified organisms (GMOs) and their products, and the introduction and management of invasive alien species and genotypes. *Biosecurity* is a holistic concept of direct relevance to the sustainability of agriculture, food safety, and the protection of the environment, including biodiversity.

FAO TECHNICAL CONSULTATION ON BIOSECURITY AND ITS OUTCOME:

In order to broaden awareness of *Biosecurity* and to debate its relevance and practicality more widely, particularly in relation to the needs of developing countries and countries with economies in transition, FAO convened an international Technical Consultation in Bangkok, 13-17 January 2003, with the participation of 38 countries and eight international organizations, including *Codex Alimentarius*, the IPPC, OIE, and the CBD.

Need for Biosecurity

- Rapid transboundary movement of men and materials
- Removal of quantity restrictions in international trade
- Threats posed by incursion of pests and diseases of plants, animals and human
- Threats posed by LMO's
- Threats posed by bioterrorism

Basic Concepts of Biosecurity

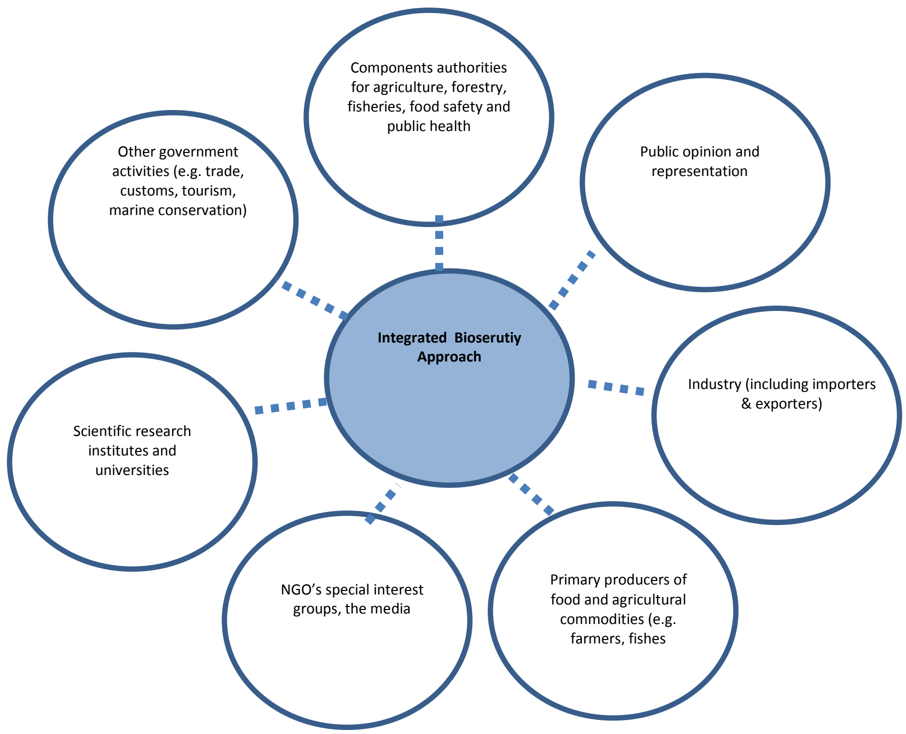
- Biosecurity is a holistic concept of direct relevance to
    - I. Sustainability of Agriculture
    - II. Wide ranging aspects of public health
    - III. Protection of environment including biological diversity

Some factors influencing biosecurity

- Globalization

- New agricultural production and food processing technologies
- Increased trade in food and agricultural products
- Legal obligations for signatories of relevant international agreements
- Increasing travel and movement of people across borders
- Advances in communications and global access to biosecurity information
- Greater public attention to biodiversity, the environment and the impact of agriculture on both
- Shift from country independence to country interdependence for effective biosecurity
- Scarcity of technical and operational resources
- High dependence of some countries on food imports

Sector interests that are important to an integrated approach to biosecurity



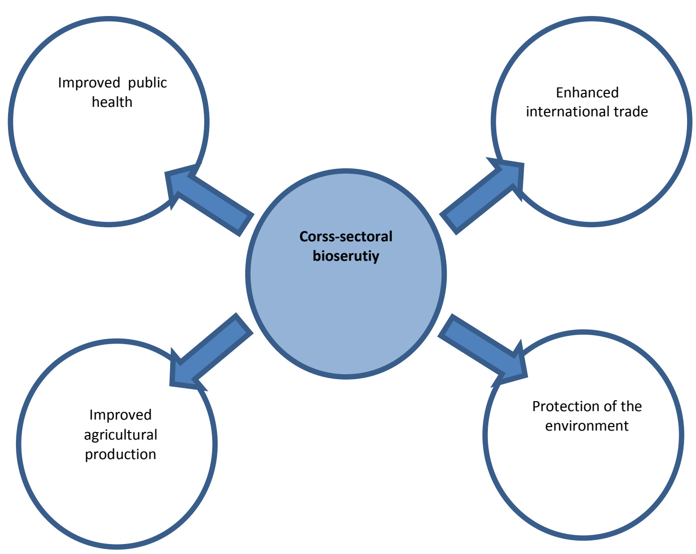
Relevant International Legal Instruments and Agreements

- In addition to the standards and related texts developed by the CAC (*Codex Alimentarius*), the OIE and the CPM, several other international **legal instruments, agreements and texts** are relevant to **biosecurity**.
- They are:
    - SPS (Sanitary and Phytosanitary)Agreement
    - TBT (Technical Barriers to Trade) Agreement
    - CBD (Convention on Biological Diversity)
    - CP (Cartagena Protocol on Biosafety)
    - International Health Regulations

Harmonized and Integrated Approach to Biosecurity

- Human, animal and plant life and health and protection of the environment are inextricably linked and this is the fundamental rationale for an integrated approach to biosecurity at the national level.
- Biosecurity hazards of various types exist in each sector and have high potential to move between sectors
    - Many animal pathogens readily infect humans
    - Animal feed may be contaminated with mycotoxins and plant toxins
    - Transfer of pests of plants between biosecurity sectors may occur on a lesser scale, inadequate control can have impacts well beyond plant health

Potential benefits associated with a cross-sectoral approach to biosecurity



Biosecurity Risk Analysis

- Many aspects of risk-based approach to biosecurity are shared by the different sectors concerned and this provides an essential impetus to risk analysis as a unifying discipline in biosecurity.
- Risk analysis is composed of three distinct but closely connected components:
    - Risk Assessment
    - Risk Management
    - Risk Communication

International level

- International legal instruments
- Intergovernmental organizations
- Risk analysis policy
- Scientific capability
- Development of standards and guidelines
- Monitoring and surveillance using international reporting systems
- Information servicing

National level

- Policy and legislation
- National biosecurity strategy
- Infrastructure
- Scientific and research capability
- Development of standards and guidelines
- Implementation of standards
- Emergency preparedness and response
- Monitoring and surveillance
- Communication systems
- Training

Basics of Risk Analysis

- The Risk analysis should determine:
  - What can go wrong?
  - How likely is it to go wrong?
  - How serious would it be if it went wrong?
  - What can be done to reduce the likelihood and/or seriousness of it going wrong?

CASE STUDY- BIOSECURITY SYSTEMS IN OTHER COUNTRIES:

- **Norway** has been through many fazes in relation to a reform process of the country's food safety administration. On 1 January 2004, the process culminated in the establishment of a 4-pillar reform, represented by the establishment of **a new authority**; the Norwegian Food Safety Authority, reorganized scientific support pertaining to the food chain through the establishment of an **independent risk assessment** body, **a new Food Law**, merging 13 separate Acts and a **new clarification** of the **relevant ministries' constitutional responsibilities**.
- **New Zealand**: The Government released New Zealand's first Biosecurity Strategy in August 2003 published by Biosecurity Council. With the bringing together of Biosecurity New Zealand with the border services functions of MAF in 2007, MAF Biosecurity New Zealand was created. The strategy raises public awareness and understanding of biosecurity. Number of other strategies such as Surveillance strategy, Science strategy, response foundations and border systems had been developed to support biosecurity system. New Zealand has played a role model in formulating a Biosecurity Act in 1993 itself, well ahead of the global need.
- **Australia**: Biosecurity Australia is the unit within the Biosecurity Services Group, in the Department of Agriculture, Fisheries and Forestry, responsible for recommendations for the development of Australia's biosecurity policy. Biosecurity Australia provides science based quarantine assessments and policy advice that protects Australia's pest and disease status and enhances Australia's access to international animal and plant related markets.
- In the US, agricultural biosecurity is looked after by the Animal and Plant Health Inspection Service (APHIS) headed by an 'Administrator' under the US Department of Agriculture. The APHIS constitutes various divisions including animal care, plant protection and quarantine, biotechnology regulatory services, wild life services etc. supported by the office of emergency management and homeland security as well. The Department of Homeland Security was created in 2002 with as many as 22 agencies including the US Department of Agriculture's Animal and Plant Health Inspection Service. The Homeland Security Advisory System is designed to give guidance on protective measures when specific information to a particular sector or geographic region is received.

ECNOMIC IMPORTANCE OF DIFFERENT VARTEBRATE PESTS

I. PRIMATES

Primates possess the mammalian characteristics of endothermy, bearing live young and feeding their young with milk produced by mammary glands. In India crop damage is very common with the several primate species, which leaves in and around human habitations on the out skirts of village, towns and cities where they do considerable damage to crops, vegetable fields and orchards.

Crop raid by many primate species have are also been reported such as Hanuman langur (*Semnopithecus entellus*), Rhesus macaque (*Macaca mulatta*), Assamese macaque (*M. assamensis*), etc.

Rhesus macaque / Bandar (*Macaca mulatta L.)*

Orange-red fur on its loins (or: lumbus) and rump distinguishes it from other primates. The hair on its crown radiate is backwards from the forehead without parting. The rhesus macaque is both terrestrial and arboreal. This is a diurnal species.They live in large troops close to human habitat. They feed mainly on the ground. Capture and exports have depopulated many areas. They consumes a wide variety of food including leaves, fruits, flowers, insects, grains, grass, algae, and will raid crops, gardens and garbage cans for food (Makwana,1979).

Bonnet macaque (*Macaca radiate* L.)

Bonnet Macaque is dusky brown to golden yellow in colour. They have black ears and black lower lips. The females usually have red face. Longevity exceeds to more than the 30 years. *Macaca* species of monkeys also become occasional pests to fruit crops (Prakash and Rao, 1988). This species is found in both evergreen and wet deciduous forests, and also in urban areas. The lion-tailed macaque is an endangered species. They feed on ripe fruits, seeds, nuts, flowers, invertebrates, squash, coconuts, peanuts, coffee beans, rice and cereals. This species has cheek pouches to carry food.

Hanuman langur (*Presbytis entellus* L.)

It is believed to be one of the old world monkeys belonging to the genus *Semnopithecus*. They are terrestrial in nature. Hanuman langur is also known by the name of gray langur and common Indian langur. Gray langur is believed to have derived its other name, Hanuman Langur from the Hindu Monkey-god, Hanuman. It is said that the langurs helped Lord Hanuman in the battle of Lanka. The langurs survive on a diet comprising of leaves, fruits, buds and flowers. However, they change their diet from season to season. During winters, they feed on matured leaves. In summer season, they mainly survive on fruits. Insects, tree bark and gum also supplement their diet. Hanuman langurs can easily digest seeds with high levels of the toxins and can eat even soil and stones. Monkeys cause tremendous damage to some ripening crops and fruits and the monkeys can also not be killed due to religious sentiments.

II. UNGULATES

The term ungulates refer to animals with hooves. Hooves are composed primarily of keratin. Except pigs all ungulates are herbivores. Ungulates are herbivores have teeth that are specialized for eating plant material. Their incisors are adapted for plucking the plant material. They have large molars that are flat and square. Large wild ungulates like black buck, *Antelopa cervicapra*, Blue bull, *Boselaphus tragocamelus* make severe damage to *kharif* and *rabi* crops like wheat, chickpea etc. They also de-bark the trees during hot months (Prakash and Rao, 1988).

Antilopes

The term antelope is applied to denote a genus of Mammalia. Both sexes are generally provided with horns. The dental formula of the teeth exhibits a want of incisor teeth in the upper, and six incisors in the lower jaw. Canines are totally wanting in the upper jaw, two in the lower jaw and twelve molars in each jaw. The horns are chiefly cylindrical in shape, but may be twisted in an annular or spiral manner.

Black buck (*Antelope cervicapra* L.)

It is the sole representative of the genus Antilope. It is also called as Kala Hiran. In Hindu religion Black buck is a vehicle of Chandamama (moon). Males dark brown in color and has ringed horns that have a moderate spiral twist of three to four turns. Black bucks have the capacity to run 50 miles per hour and is one of the fastest animals in the world. Females attain sexual maturity much faster than the females. Male black buck attain their sexual maturity in three years and the female in two years. Gestation period rests for ten months. Females can give birth twice in the 14 months to one or two young ones at a time. Young ones remain with their mother up to the age of one year.

They damages important agricultural crops viz*.,* wheat, barley, jowar, bajra, moong bean, mustard and cotton. Crop damage to *Sorghum* caused by the endangered blackbuck antelope *(Antelope cervicapra)* was estimated by (1) comparisons between grazed and ungrazed biomass, and (2) the dietary needs of a known population of blackbuck.

Sambar deer (*Cervus unicolor L.)*

Sambar deer stands to a height of 135 -150 cm can weigh up to 300 kg. Males have antlers measuring up to 1m. It is characterized with large muzzle and broad ears. It has thick fur and orange spots on its body. Males are larger than the females. Males have thick mane of hairs around the neck. They are found in almost every corner of India and their population is more in central India. Sambars are found in habitats ranging from tropical seasonal forests, subtropical mixed forests to **tropical rainforests**. They are seldom found far from water. The breeding period is mainly during the months of November and December. The gestation period rests for almost 6 months after which single offspring is born. The life expectancy of Sambar Deer exceeds up to 16 -20 years of age. Sambars have lived for up to 28 years in captivity, although it is unlikely that they often survive more than twelve years in the wild. (Semiadi, G. *et al,*. 1993).

They prefer marshy and wooded areas to live. They feed on leaves, vegetation, herbs, fruit, bamboo buds and mushrooms. They prefer Jowar, pigeon pea, green gram, chickpea, groundnut, vegetables and fruit crops. The extent of damage ranges between from 10 to 25 per cent. Damage intensity varies from location to location.

Chital (*Axis axis* L.)

Chital are 90 cm tall and it has white spots all over the body. They shed their horns annually. These antlers are used in mating displays and for the purpose of protection. They found across the entire country except in the extreme northern regions. They are usually found in the herds of 10 - 20 individuals. Chital occur sporadically in the forested areas throughout the rest of the Indian peninsula. However it currently occurs only in the Sundarbans in Bangladesh as it became extinct in the central, north-east and south-east regions. **(**Sankar and Acharya 2004). Chital reach the sexual maturity at 12 -14 months. It breeds in either the summer or winter. However, it is mostly seen during the summers, when males can be seeing throwing their heads back and letting out loud mating calls. Gestation lasts for seven months. Females give birth to one to three fawns. Lifespan of the Chital is around 20 -30 years.

Their diet consists of all kinds of vegetation. They enter into the crop fields and create severe damage. Chital prefers wheat, fruits, herbs, flowers and leaves. In Tamilnadu it is reported to cause damage in the vegetable crops mainly Chilli. They feed for four hours after sunrise and for two hours before sunset.

Blue bull / Nilgai (*Boselaphus tragocamelus* L.)

It is one of the most commonly found wild animals of northern India. Even though it is an antelope, it looks quite similar in appearance to an ox. Therefore, it has been given the name of blue bull of India. The average lifespan of the Neelgai is 21 years. Neelgai are widely found in the jungles of Karnataka, Rajasthan, West Bengal, Assam and Haryana. It grows to length of somewhere between 1.8 and 2 m and weighs around 120 to 240 kg. Neelgai reach the level of sexual maturity in 18 months. They do not have specific breeding season and the gestation period rests for 275 days. Usually twins are born at a time. Female is yellowish-brown in color and is shorter in height as compared to her male.

Nilgai is a highly adaptive antelope. Naturally diurnal, it goes for crop-raiding in the evenings and at night. It is found to damage most agricultural crops to a considerable extent. Estimates are being made. However, it shows preference for gram, wheat seedlings, and moong and fruits. In case of blackbuck, the feeding is maximum in the mornings, and during rest of the daytime the animal is found either grazing in the open areas or resting. Damage caused by nilgai is much more than blackbuck.

Indian Wild Boar (*Sus scrofa L.*)

Wild boar is also known as wild pig, is a species of the pig genus *Sus*. Its head is larger and more pointed than that of the European boar, and its ears smaller and more pointed. Wild boar is often serious problem to sugarcane and groundnut crops. They are found in southern Himalayas to central India. *Sus scrofa cristatus* is found in southern India. Adult males are usually solitary outside of the breeding season, but females and their offspring live in groups called *sounders*. Sounders typically number around 20 animals, although one will be the dominant female. Litter size is typically 4–6 piglets but may be smaller for first litter, usually 2–3. The sex ratio at birth is 1:1. They will begin to eat solid foods such as worms and grubs after about 2 weeks. Wild boars are crepuscular or nocturnal, foraging in early morning and late afternoon or at night, but resting for periods during both night and day. They are omnivorous scavengers, eating almost anything they come across, including grass, nuts, berries, carrion, nests of ground nesting birds, roots and tubers.

Wild boar caused maximum damage to maize crop (14%), followed by wheat/barley (6%) and rice (5%). And also can damage to guar (25%), oil seeds (17%), wheat/barley (15%), pulses (13%) and jowar/bajra (12%).

Elephant

Elephants are the largest terrestrial mammal of India. There is a huge conflict between human and elephant and vice-versa because of degradation of forest and encroachment activities. Asian elephants show seasonal movements and use of these habitats influenced by water and forage availability. Male elephants join a herd usually during mating season. They found in South India (Western Ghats), North East India and the Sub Himalayan Region. The gestation period is 18 to 22 months. Only the male elephants have tusks, which can grow up to five feet long. The average lifespan of an Asian elephant in the wild is up to 60 years. All elephants are herbivores, which mean that they eat only plants and vegetation. They are also dependent upon cultivated crops, bark, root, twigs, fruits and leaves. They are one among the herbivorous animals. An adult elephant can consume up to 300 pounds of food and 100 to 150 lit. of water in a single day.

They eat less and destroy more. The crops are easily destroyed as the elephants move about in the fields. The farmers try to scare them with fire and by beating drums but all our efforts remain fruitless because they are now habituated with these ploys. Forest officials said wild elephants are found frequenting human habitations lately as there has been a sharp decline in forest cover due to rapid industrialization in the district.

Golden Jackal / Fox *(Canis aureus* L.*)*

The golden jackal is very similar to the wolf in general appearance, but is much smaller in size and lighter in weight, and has shorter legs, a more elongated torso and a shorter tail. The head is lighter than the wolf's, with a less-prominent forehead, and the muzzle is narrower and more pointed. Golden Jackals are found in the variety of habitats, mostly spotted in the semi- desert, evergreen forests, savannas and agricultural and horticultural crop fields. Female fox give birth to 4-5 young ones in an spring season. They are of medium size, females are smaller than the males. They live 2-3 years but can survive for 10 or more years in captivity. Gestation period rests for nine weeks. Litter size is 3-6 pubs. The life span is 14-16 years.

Golden Jackals are omnivorous in nature. They feed on small mammals, insects, hares, fish, birds and fruits. It generally consumes around 1 kg of food for every day. They are known to store their food for latter consumption. They damage crops like maize and groundnut.

Indian flying fox (*Pteropus giganteus*)

Face looks like a dog's, so they called as flying fox. They are nocturnal mammal. No sexual dimorphism is noticed. Fruit bats live in large groups called ‘camps’. They have long, webbed fingers that serve as wings. By day the Indian flying fox roosts in communal sites, called *camps,* hanging upside down in a large tree. Favored roost sites are often used for many years, and the trees become stripped of bark and foliage by the bats' sharp claws. The gregarious habit of fruit bat, *Pteropus giganteus* results in colossal loss to fruit crops like ficus, guava, mango, litchi etc. Flying foxes are the largest of all bats and are found widely throughout Asian countries and Australia. They live in tropical forests and swamps, primarily in coastal areas. They breeds during July to October, gestation period is about 140 - 150 days. They produce one to two live young. It Roosts in colonies, active at night and the average lifespan is 15 years.

Short-nosed fruit bats inflict serious damage on many of the horticultural crops *viz.,* apple, banana, pineapple, mango, sapota, guava and grapes. The bats have good sense of eyesight and smell to find their food. They also feeds on flowers and nectars and play major role in pollination and seed dispersal.

III. LAGOMORPHS

Indian Hare (*Lepus nigricollis* L.)

Hares and jackrabbits are leporids belonging to the genus *Lepus*. A hare less than one year old is called a leveret. Hares are very fast-moving animals. They live solitarily or in pairs, while a "drove" is the collective noun for a group of hares. Hares are normally shy animals. A single species of Lagomorph causes isolated damage to crops near hillocks and forests, where enough cover is available for their activities. The Indian hare is distributed throughout India, except the high reaches of the Himalayas and mangrove areas within the Sundarbans in the state of West Bengal. Lepus nigricollis can be seen in wide variety of habitats such as short grasslands, barren agricultural fields, crop fields, and forest roads. It breeds throughout the year, but the peak breeding season is during the monsoon season. Litter size is one to four, but can be higher (Gurung and Singh 1996). Forbs and grasses constitute the bulk of their diet. *L. nigricollis* is characterized as a shy species. It exhibits activity during crepuscular and nocturnal hours. It will cause damage to agricultural crops, vegetable and horticultural crops.

ECONOMIC IMPORTANCE OF RODENTS IN AGRICULTURE AND HORTICULTURE

1. Introduction

Order Rodentia makes up almost 40 per cent of mammal species and represent the largest order of mammals, comprising >2000 species in 34 families that include 389 genera throughout the world. In India, 4 families (*Sciuridae, Dipodidae, Muridae and Hystricidae)*, 43 genera, and 104 species represent rodents. Among them about 14 species are of economic importance.

Rodents are agricultural, storage and household pests throughout the country causing direct damage to various commodities by gnawing and feeding and indirect damage by spoilage. They are the most important ones among vertebrate pests due to their high adaptability to live successfully in man-made environments. The group is given the name due to their gnawing teeth (*Rodere* = to gnaw; *dent* = teeth), which provide them access to closed places and packaging material and food sources.

Since they are prolific breeders and the young mature quickly their presence could be felt by their damage to edibles and non-edibles that make humans to go for their control. Further, their cryptic life style and relatively small body size tend to complicate their control activities. Since they are also mammals, safety considerations in relation to the human population also keep a tab on the usage of rodenticides.

Urban areas, the houses, animal sheds and food stores provide permanent source of food and shelter to these pests due to their poor quality. Control actions in such conditions are very difficult since they require inputs for efficient proofing operations. Proofing will often be done poorly or with inefficient material resulting in free access for rodent entry into these buildings/structures.

Normally people expect that control actions should kill visibly large number of rodents. Thus, they would like to see immediate result of the action. Habitat manipulation, sanitation operations or preventive control and the use of modern anticoagulant rodenticides do not result in visibly dead animals. As a result, most of them doubt the affectivity of control actions. In many cultures, humans developed tolerance to rodents and accept them as a fact and they rarely understand the close relation between rodents and certain diseases. In other places, rodents are an important source of proteins or they are even worshiped. These facts make it imperative of motivating local community for bringing out effective rodent control results.

2. ECONOMIC IMPORTANCE OF RODENTS

Agriculture in general is organised in small plots that are loosely dispersed and intermixed with fallow land. These habitats are efficient breeding grounds for rodents in lien period or also when the crop is not at a vulnerable stage. Due to this they are able to inflict significant crop damages in the country. In addition, they also contribute in contamination, deterioration of consumable items and enhance susceptibility to fungal and bacterial infestations to human beings.

2.1. PRE HARVEST DAMAGE

The net area sown in Tamil Nadu is 50.61 lakh hectares (2007-08). The major food crops grown in Tamil Nadu include rice, jowar, ragi, bajra, maize and pulses. Cotton, sugarcane, coconut, tea and coffee are also grown and considered as cash crops. Significant crop losses due to rodents are reported from Cauveri delta districts. Studies conducted by A V C College, Mailaduthurai during 1993 to 1995 indicated that magnitude of crop losses caused by rodent pests in the Cauvery Delta were 60.99% in rice, 64.8% in black gram, 60.99% in green gram, 11.28% in sesamum, 11.24% in oil palm, 44.44% in pine apple, 55% in cotton and 21.6% in groundnut. Although these were the years of rodent outbreak in Cauveri Delta, significant rodent damages are not ruled out in other years also. Most of the rodent damage estimates relate to the mature or pre harvest stages of the crops but rodents cause damage at almost all stages of the crop from sowing to harvesting.

Reliable National estimates of the damages caused in pre harvest stages of the crops are not available except limited studies conducted at different places. However, the nature of damage and estimation protocols for identified crops is given as under:

2.2. Nature of rodent damage

Rice

Paddy is grown in large excess because rice is the main staple food of the state. There are three crops based on duration. The first one is the *'Kuruvali'* (the short term crop) with duration of three and a half to four months from June to July to Oct - Nov. The second crop is called the *'Thaladi'* that grown in 5 to 6 months Oct - Nov to Feb - March. Third is *'Samba'* and has duration of almost 6 months from Aug to January. The major source of irrigation is the rivers, tanks and wells. The state has an area of 17.89 lakh hectares under rice with a production of 50.40 lakh tones. Rodents damage rice crop in all the stages of growth. They cut diagonally tillers normally 5-10 cm above the water level. Significant damage starts from the time of active tillering and it will be higher during early growth stages and decreases later, when rodents feed on more nutritive panicles. The extent of pre harvest rodent damage reported in India ranges from 0.44 to 60.8% of tiller damage. The distribution of damage is highly variable.

During *isolated damage* patches of severe damage are visible within the fields, while at *scattered damage* fields appear undamaged but possess evenly distributed damage. Boarder rows sustain little or no damage as a protective instinct. They make damage away from the bund by swimming in the irrigated water. As per studies during 1959-69 in All India Coordinated Project on Field

Rats, the damage patch distance varied from the size of the field and normally lies between 1 to 12.6 meters away from the bund. Spacing of 9 X 4 inches during Kuruvai and 12 X 6 inches in Samba crop exhibited minimal rodent damage in the crop.

A direct relationship between the number of live burrows and damage exists in rice. In addition to damage to the tillers, rodents also hoard the grain in their burrows in special chambers. In addition to making tiller damage, they also hoard the panicles in their burrows. The extent of the hoarding ranges from 0.5 to 4 kg per burrow by the lesser bandicoot rat (*Bandicota bengalensis*). An extent up to 4 kg/burrow is reported through the ICAR Network project's trials.

Sugarcane

Sugarcane is grown in 5.3 lakh hectares with a production of 380.71 lakh tones. Rodents damage sugarcane crop by eating buds of seed sugarcane pieces, apical growing points of young and mature stalks and millable part of the cane.

In addition, their burrowing habits lead to damage to the root system leading to the total cane drying. The crop provides good harborage to the rodents, especially if the crop is lodged or not propped unlike in other crops. Even small damage to cane leads to the infestation by insect pests such as termites and diseases such as red rot. Rodent damage, thus, leads to either drying of the cane or deterioration in cane quality through fermentation of cane juice. A study conducted by Sugarcane Breeding Institute, Coimbatore shown that CO 6304, COC 671 and COC 8001 had more rodent damage compared to other varieties. The cane damage was reported to be up to 44% and internode damage was 28%,

Coconut

ICAR Coordinated Project reported a nut loss of 10-15 per cent in coconut in the state, with 40 to 60 per cent of the palms infested by the House rat.

Vegetable and fruits

Vegitable are usually grown with irrigation water it will provide an optimum micro-climate for rodents. In vegetable fields near hilly terrain, the porcupine damages tuberous crops, potato, sweet potato and carrot. F. palmarum causing damage to fruits like pomegranates, black barries, guava etc. the unripe fruits are nibbled and dropped from the trees, and the ripe fruits are scooped from inside and a large number are broken off the branch and dropped to the ground. The serious damage to apple in HP. Rodents inflict considerable damage to vegetable crops. It is estimated to be 8.7 and 10 % in Rajastan and Gujarat, respectively. In water melon crops the damage sometimes reaches from 70 to 80%. Similarly orchards are also severely attacked by gerbils, squirrels are major rodent species attacking the kitchen garden and fruit orchards.

3. **Major groups of rodent pests**

Rodent Groups

Different groups of rodents occurring in India include squirrels, gerbils, bandicoots, rats and mice. Both pest species as well as species that require protection exist in the State. For example the Giant squirrels and flying squirrels reported in Western ghats of the State are threatened species and require protection. Giant squirrels live in on tall trees in the forest habitats of the Western ghats feeding on leaves, grasses and seeds of various plants. Indian porcupine, *Hystrix indica* with hair modified as quills is seen at rocky hillsides devouring mostly tuber crops. However, flying squirrels and porcupines are protected under Wildlife Protection Act (1971). The major groups of rodents, which have economic importance in India are bandicoots, rats, gerbils, voles, and mice. The major pest species in these groups are discussed below:

3.1. Squirrels

The bushy tail of these animals characterizes the squirrels under Family Sciuridae. The State has wide distribution of 3 -striped squirrels.

Southern palm squirrel (*Funambulus palmarum*)

It has bushy tail with dorsal surface having three distinct white stripes. Hence this is also called as 3-striped squirrel.

Distribution: In the plain region of the state the species are scattered.

Habitat: It inhabits horticultural and plantation crops.

Habits: It is a diurnal rodent and lives in the trunks of trees/rocks and orchards. It breeds from March to September with a litter size ranging from 1-5. The gestation period is 42 days and maturity period is four months.

Pest status: It is a serious pest in cocoa. It is also reported to make losses in cardamom and dwarf varieties of coconut.

3.2. Gerbils

Gerbils represent the subfamily Gerbillinae under Family Muridae. They are characterized by the presence of *tassel* (a tuft of hair) at the end of the tail. Only Indian gerbil is distributed in the state.

Indian gerbil (*Tatera indica*)

It is a medium body weight rodent (100-250 g.) with light brownish dorsum and longer tail (120%) than head and body. The eyes are large, rounded ears and bicolour tail with terminal black tuft. Feet are whitish and with eight mammae.

Distribution: In the plain regions of the state Indian Gerbil, *Tatera indica* has normal distribution.

Habitat: Inhabits dry land crop fields, fallow, and wastelands.

Habits: Nocturnal and fossorial. The burrows have semi circular openings with zigzag shape and 2 to 4 openings and emergency exits. These gerbils prefer making burrows mostly sandy soils. They are dry rodents and can tolerate water stress and hence became pests for dry land crops.

They are gregarious in habit. Seeds of grasses are eaten mostly during post monsoon and winter seasons and, leaves and flowers all though the year. It breeds throughout the year with peak activity during post monsoon months with a litter size ranging from 1 to 9 (mean 4.8). The annual productivity is 17.72 young ones per female.

Pest status: It is a known pest in South Tamil Nadu affecting cotton and groundnut crops. It is also a reservoir for plague disease and hence it has more public health value.

3.3. Bandicoots

Among bandicoots, the Indian mole rat, *Bandicota bengalensis* is reported as major pest in the State, although the Larger bandicoot, *Bandicota indica* can be seen in cities.

Lesser Bandicoot Rat (*Bandicota bengalensis*)

This Indian mole rat is a robust rodent (around 200 to 300 g body weight) with a rounded head and a broad muzzle.

Tail is shorter than head, body, and dorsum with dark brown colour and coarse hair.

Distribution: It is transported through human agencies and established in the field as well as in houses.

Habitat: *B. bengalensis* although found in various ecological conditions is a wet rodent and hence depends on mesic conditions. As a result it is seen on the embankments around rice cultivation and irrigated fields.

Habits: It is a nocturnal and fossorial, lives in self constructed burrows. It hoards the grain. The burrows are characterised by the presence of scooped soil before the entrance. Sometimes these openings are closed with soil plugs for regulating temperature and relative humidity inside the burrows.

They breed throughout the year with peak activity coinciding with the maturity of *kharif* and *rabi* crops. However, males are reportedly fecund all through the year. The oestrus period varies from 3 to 5 days and gestation period is 22 days. Litter size range from 1 to 11 (mean 6.2). It litters 9 to 11 times a year producing about 70 young ones per annum per female with a post partum period of 30 days.

Pest status: It is a major pest in the state. It is also a vector for leptospirosis. Incidence of Leptospirosis is reported in few districts of Tamil Nadu.

3.4. Rats

These are the most predominant animals under Sub family Murinae in Family Muridae. There are several pest species in this group.

1. The Norway rat (*Rattus norvegicus):*

This short tailed brown rat has blunt nose and small eyes distributed in port towns of coastal areas.

Habitat: Nocturnal and digs extensive burrow systems along foundation of buildings, under concrete or near rubbish piles in soil.

Habits: They are omnivorous and breed all through the year. Gestation period is 24 days with 3-7 litters per year. Litter size range from 6-10 young ones. Sexual maturity attained in 3 months.

Pest status: It is more a vector species for Leptospirosis than pest.

1. The House Rat (*Rattus rattus*)

Medium sized (80-120 g.) rodent with bicolour and ringed tail that is longer than head and body length. It is also called as Black rat or Roof rat. It has bicolor tail and nocturnal in habit.

Distribution: This is the most prevalent house dwelling rodent living with *Mus musculus* in the residential premises and storage units. They also live in colonies on the crown of coconut trees in the state.

Habitat**:** This rat is partially social and lives inside residential premises and storage areas.

Habits: It is generally nocturnal. It is a good climber with longer tail to balance and lives on roofs of residential premises. It breeds throughout the year producing 5 to 7 litters a year. Gestation period is 22 days with a litter size of 6-14 young ones.

Pest status: It is one of the most important pests of stored grains and fruits in the state. It is also a vector plague and leptospirosis diseases. It is a serious pest in coconut and cocoa.

3. Soft-furred field rat (*Millardia meltada)*:

It is a small rodent (40-60 g.) with soft fur, dorsum light Grey and bicoloured tail equal or shorter to head and body. It occurs in regions where moderate soil moisture is available to the vegetation all the year round.

Habitat: Inhabits irrigated fields, in clear patches and in hedges and grasslands. It is a semi mesic rodent and hence found mostly in semi arid areas. It is associated with *T. indica* and *Mus booduga* in Northern India, while in Southern India it occurs in association with *Bandicota bengalensis*.

Habits: It is nocturnal and fossorial with simple burrows. The burrows are small. It thrives upon crop plant parts and grains, which constitute about 63.3 per cent of the total food intake. It has oestrus cycle of 4-5 days and gestation period of 20 days. The litter size is 2-10 with an average of 6. The annual productivity is 52.5 young ones per female.

Pest status: It is comparatively a minor pest. However, it is associated with damage to cotton at sowing and boll stages and in groundnut at pod formation stage.

3.5. Mice

Among all rodents, mice are the smaller animals with more resilience and reproductively making them not only as pests, but also as nuisance animals causing damage to non-edible articles due to their nibbling behaviour.

House Mice (*Mus musculus sp*.)

Dark house mouse, *Mus musculus homourus* with whitish under surface is found in the fields as well as in the houses, living in burrows, below rocks and in crevices. It is omnivorous and causes lot of damage to grains and stored food material. They are small rodents (15 g.) with bicolour tail longer than head and body. The dorsum is dark brown to sandy.

Distribution: They are pests in all places of the State.

Habits: They are nocturnal, fossorial and highly active and have nibbling habit, which result in damage to sacks and foods. Breeds throughout the year with a litter size of 1-8 (Mean 5.6) young ones, oestrous period of 5.7 days, and has a gestation period of 18 days. Young ones reach maturity in 45 days.

RODENT BEHAVIOR IN RELATION TO THEIR MANAGEMENT

Rodents are social animals which live in colonies/solitarily. They prefer ground dwelling, like to live near water of any sort, and prefer foods rich in carbohydrates and protein. The preferences, though, are only preferences, as Norway rats can adopt to almost any situation. This allows them to thrive in conditions of hot or cool. Rats will also kill and eat animals including small mammals, reptiles, birds, and cockroaches. Unlike mice, rats cannot survive without open water requiring about an ounce of water daily. This doesn't particularly limit their choice of habitat as they can obtain their water from toilets, sinks, rain puddles, dew of plants, and condensation off of utility pipes. The physical capabilities of rats are extremely alarming. They can climb stairways, pipes, wires and even bare walls with a rough surface. Most rat populations are nocturnal operating between dusk and dawn. They will adjust, however, to feed during times which food is the freshest or most available. They have many behavioural adaptations which are given below:

FOSSORIALITY

Generally rodents live in fossorial (live under the ground) but in Indoors, rats prefer to nest on ground levels, though they will move to upper levels and attics when populations are large enough. Squirrels live in arboreal habitats, live in tree holes/cracks and crevices. Nests may be located in wall voids, underneath floors, in crawl spaces, underneath and behind stationary equipment, and in stored pallets or piles. These rats have even been found nesting within furniture in rooms which the occupants frequent. Outdoors, nests are often burrows located around the foundation of the structure. These burrows will become expanded and enlarged as the rat population grows. Many burrows may interconnect with one another forming a complex network of underground tunnels. These burrows will contain one main entrance, as well as two bolt holes which are used for escape purposes. Constant environmental conditions will be maintained inside the burrows, facilitated by soil. The depth normally depends on the atmospheric temperature

- Porcupines – make crevices between rocky areas; the crevices are normally tapering; complex of crevices due to gregarious living.
- Bandicoots – scooped soil exists before the burrows with soil pebbles.
- Soft furred field rat – vertical burrow, which extends laterally
- Gerbils – the burrow is complex in nature

NOCTURNALITY

They are crepuscular (Active mostly after dark), but are adaptable if warranted by circumstances; indoor mice are generally nocturnal but less predictable than rats. The spontaneous activity starts at evening hours after sunset and have exploration, feeding and feeding rhythms; the activity will be minimize by 9.30 pm. Again they become active in early morning having exploratory and feeding activities.

EXPLORATION

Rodents have a habit of checking the environment during the spontaneous activity period. This is to guard the area where they live to check any incursions or change in the environment. This is an in born instinct of all rodents.

THIEGMOTAXIS

Prefer to travel along, and in contact with, vertical surfaces rather than in the open; wary of crossing open spaces that provide no cover. In field conditions they prepare to move side of the bund. Hence, the baits placed on the bund are not accepted. Territories of most of the rodents ranging from 50 to 150 feet from the burrow, however, rats will travel up to 300 feet to a food source. As rat populations grow, competition, conflict, and fighting begin to increase. Large males will become dominant and any given territory can be divided up into several social orders where subordinate males also maintain an smaller area. Many rats will often be seen during the day, as they must feed when larger dominant rats are inactive.

AGONISTIC BEHAVIOR

Agonistic behavior refers to the complex of aggression, appeasement and avoidance behavior that occurs between members of the same species. Agonistic behavior is a much broader term than "aggression," which refers to behavior patterns which serve to intimidate or damage another (for more, see McFarland, 1982).

SOCIAL AGONISTIC BEHAVIOR

Agonistic behavior involves several actions, or motor patterns, including chasing, sidling, boxing, biting, and kicking, as well as audible and ultrasonic vocalizations. Agonistic behavior can occur between rats in a colony, and between resident rats and intruders.

Urine Marking

Urine Marking in rats refers to the deposit of drops or smears of urine in the environment, sometimes accompanied by secretions from preputial sebaceous glands (Birke 1978). Urine marking is a type of scent marking, a form of *chemical communication*, in which one rat, the *sender*, generates a chemical signal (the drop of urine) and transmits the signal by depositing the drop in the environment. Another rat, the *receiver*, identifies, integrates and responds (either behaviorally or physiologically) to the signal. It is assumed that the sender-receiver relationship is the result of natural selection, such that the sender's signal produces a response in the receiver that benefits the sender in some way (e.g. the signal attracts a mate for the sender etc.), while the receiver assesses the signal and responds in a way that most benefits the receiver (Agosta 1992). Urine marking is very common in mammals, and it has become adapted for use in a variety of contexts and may have more than one function in any given species. In addition, it may have different functions in different species (Johnson 1973). Chemical secretions contain an enormous amount of information (Agosta 1992). A rat who smells a urine mark can determine all sorts of things about the rat that produced it: its species, sex (Brown 1977), age (juvenile vs. adult), reproductive status (Carr and Caul 1962), familiarity (Krames and Shaw 1973), social status (Krames *et al.* 1969), individual identity (Brown 1988, Carr *et al.* 1970), and current stress level (Mackay-Sim 1980, Giesecke 1997, Valenta and Rigby 1968). In addition, rats can tell how long in the past a urine mark was deposited.

NEOPHOBIA

Rats constantly explore their territories and are very wary of new foods, new objects, or changes in their environment. This behavior is known as neophobia and can last up to several weeks. This has definite impacts on the Control of Norway Rats. They exhibit *bait shyness* , often not returning to food which makes them sick after taking little nibbles in initial tasting. These are extreme neophobic rats which avoid all baits and traps. The neophobic response can be one of the most pertinent obstacles to efficient rat control (Lund 1988). Barnett (1958) defined **neophobia as the avoidance of an unfamiliar object in a familiar place**. It causes problems in poisoning programmes because neophobic animals will avoid new foods and even foods previously eaten if they are placed on or in a novel object (Barnett 1988). The response varies not only between species (see below) but also between populations of the same species (Mitchell et al. 1977) and between individual animals (Cowan & Barnett 1975).

- Neophobic periods:
  - R. *rattus* – 3 days
  - B. *bengalensis* – 1 day
  - M. meltada – 5 days
  - *T. Indica* – 3 days

BAIT SHYNESS

Aversion towards the poison bait is called bait shyness. A number of researchers, especially in India, have looked at the role of various food characteristics in the development of conditioned food aversions, and aversions to different poisons (e.g. Howard et al. 1968; Bhardwaj & Khan 1978; 1979a, b; 1980; Rao et al. 1980). Thomas & Taylor (2002) noted that either bait shyness or poison resistance was apparent in the rat population on Ulva Island. Cowan et al. (1994) recommended micro-encapsulation of poisons as a way of reducing the formation of learned aversions,

by delaying the symptoms of poisoning. Sub lethal doses of acute rodenticide will not kill the rodents, but the minute quantities of phosphine generated in stomach will give stomach disturbance. Rodents will associate this discomfiture with bait material ate. Consequently they avoid eating the food item- Bait Shyness. It is temporary phenomenon.

- Persistent periods:
  - R. *rattus* – 75 days
  - B. *bengalensis* – 21 days
  - M. meltada – 135 days
  - *T. Indica* – 75 days

RESISTANCE TO RODENTICIDES

Rats can also be physiologically resistant to poisons (Thijssen 1995; Taylor et al. 1996). This is a genetic trait that has been selected for over generations of exposure to certain rodenticides (Greaves

1994;). Warfarin-resistant mice, Norway rats and ship rats have been found in England and Europe (Boyle 1960). Warfarin resistant rats can be also resistant to difenacoum (Greaves et al. 1982). The issues of bait avoidance and the efficacy of poisons against warfarin- and difenacoum-resistant rats were discussed by Quy et al. (1992). Cleghorn & Griffiths (2002) found no evidence of resistance to brodifacoum in mice from Mokoia Island. Chronic rodenticides are reported to result in development of resistance over a period of time one more number of treatments. Bromadiolone has so far not shown proven anticoagulant resistance

MIGRALITY

Rodents inherently have migrality behavior - the movement in search of food sources. There are two types of migaration occur in rodents 1. Emigration – outward movement after the harvest in search of food available areas and 2. Immigration – inward movement of rodents to the crops under establishment. The range of movements depend largely on location between food resources and suitable harborage. Under stable conditions their movement is limited. Bandicoot the home range between 55 meter to 50 meter. A Norway rat will move within a diameter of 100 to 150 ft., a roof rat, 45 to 150 ft., and a house mouse, 10 to 30 ft. This range may expand when conditions are unstable or changes, such as a construction site. They may also expand their range in protected areas such as in sewers, in passages between buildings, and under groundcovers and during seasonal or climatic change

REPRODUCTIVE BEHAVIOUR

The male courting and mounting behavior coincidental with ultrasound calling. It can be induced by female urine. Rodents have two types of reproductive behavior is given in the below table.

Normal Breeding (k-type)	Abnormal breeding (r-type)
▸ Sex ratio (M:F)- 1:1 ▸ Avg. Litter size – 6 ▸ Post partum oestrous- 90 days. ▸ Maturity period- 90 d ▸ This is seen in normal un-disturbed agrarian ecosystems	▸ Sex ratio (M:F)- 1:2 ▸ Avg. Litter size -20 ▸ Post partum oestrous- 2 days. ▸ Maturity period- 75 d ▸ This is seen during unexpected favourable climatic situations

Many factor is responsible for the reproduction it influenced by mainly peromonal communication. Here some of chemical communication responsible for reproduction they are a) The **Bruce effect**, or **pregnancy block,** refers to the tendency for female rodents to terminate their pregnancies following exposure to the scent of an unfamiliar male. The effect has primarily been studied in laboratory mice (*Mus musculus*), but is also observed in deer-mice, meadow voles, and collared lemmings. The Bruce Effect has also been proposed, but not confirmed, in non-rodent species such as the lion. In mice, pregnancy can only be terminated prior to embryo implantation, but other species will interrupt even a late-term pregnancy. B) In **Whitten effect** it refers to the male mouse pheromones will synchronize the estrous cycle of group housed females. C) In **Vanderbergh effect** referees to exposure to male urine pheromones will induce earlier first estrus in pre-pubertal females.

NON CHEMICAL RODENT PEST MANAGEMENT

Integrated pest management is a system which in the context of the associated environment and the population dynamics of the pest species, utilises all suitable techniques and methods in a compatible way and maintains pest populations at levels below the economic injury level. Rodent control is a problem of applied ecology and the control measures should be based on proper translation of ecological factors into management polity. *The primary aim should be to reduce damage, rather than to kill the pest.* However, most often this is achieved by use of a lethal chemical. However, if lethal control is followed by rapid immigration then the damage reduction may be short lived. Thus it is important to take account of spatial dynamics of the pest. Simple ecological theory treats a population as a group of organisms in one place at one time, the number of which change through time according to the number of births, deaths, immigrants and emigrants. Although rodents have potentiality for fast breeding, the geometrical progression is countered by various limiting factors operated by nature. Implantation failure, intra uterine mortality, maternal cannibalism and postnatal mortality due to social strife etc. limit their number. However, the higher carrying capacity of crop fields result in maintaining more number of rodents resulting in significant crop losses.

Factors for rodent incidence

Climate affects the food supply in nature. Based on this the rodents exhibit unimodal or bimodal peaks in breeding activity often coinciding with the crop maturity periods. Bimodal pattern of breeding is observed in *Bandicota bengalensis, Funambulus pennanti,* and *Tatera indica*. However, wherever single cropping is practised unimodal pattern of breeding is reported for these species. *Harbourage or cover* is an important parameter that limits the rodent infestation. Weeds afford both shelter and food to the rodents. Bunds with more volume have more weeds; thereby more rodent infestation. Similarly, denser fields with more tiller density afford cover and energy, which enhance reproductive activity of rodents.

Wider spacing and even maintenance of alleys in rice fields prevent rodent damage. Cover/shelter in storage of commodities is one of the major factors influencing the rodent population. Rodents are highly mobile and form limited social structures based on a hierarchy. These *home ranges* depend on food reserves, cover, and presence of other individuals of it or other species. Home ranges change with altered resources. Rodents emigrate from their ecosystems once the food source is removed or shifted. This is particularly important since rat control is done in some places at harvest time. They also immigrate very fast. Sustained trapping and poisoning which may reduce 80-90% of rodent infestation often fail to prevent the damage because of constant immigration from un-trapped and un-poisoned areas nearby.

In cereal crops booting stage attracts rodents, which on arrival settle in the field and start breeding due to abundant *availability of quality food*. This is one of the factors to planning timing the rodent control operations. Pre seasonal rat control operations are vogue in some of the States. Such control may have limited result due to this dispersal behaviour. Further the compensatory capacity of the cereal crops before booting stage also makes it imperative to take up rat control operations at late tillering stage.

Monitoring rodent incidence

Since the aim is primarily for damage reduction, but not individual rat killing, there is a necessity of monitoring the situation in different ecosystems through either their damage or through their levels of infestation. Looking at National perspective it is recommended that efforts for periodic monitoring of rodent infestation in crop fields at tehsil levels be made based on the number of active burrows per hectare (25 burrows per hectare: low intensity; 25 to 50 burrows/ha: medium intensity and more than 50 burrows/ha.: severe intensity). The control decision may be taken depending on the monitoring surveys. Limited work undertaken on monitoring indicated that damage index of 15% of rodent affected hills or 2% tiller damage may be taken as threshold value.

Rodent management measures

Different methods exist in controlling rodents. However, each method has its own limitation. The methods that are in vogue and limiting factors are given below:

Role of predators

Snakes and owls have been the natural predators for field rodents. Bird perches of 3 meter height with a 2 ft cross bar are employed for attracting owl perching in the nights to facilitate hunting the colonising rats. The perches should be used at tillering stage of the crops to tackling immigrating rodents. However, if these perches are continued in later stages, granivorous birds will cause damage to the panicles. Since most of the predators of rodents are general feeders, they often tend to feed on food other than rodents.

Declined rodent population after harvest of the crops makes these predators to leave the area on emigration. There is also sometimes a possibility of predation triggering increase in rodent populations after partial removal of the rodents. Attempts were also made with parasites and pathogens to bring successful rodent control. However, the efforts are so far not fruitful since they also equally affect human populations. Attempts are in progress to use immuno-contraception through viral vectors (VVIC) among rodents. However, the trials are at infancy stage only.

Physical methods

Trap Barrier System (TBS) is being tried in different countries employing fences to the rice farming and fixing traps at different intervals. Trap crop is also is added to attract rats to immigrate by growing a small patch of the crop on the periphery. However, looking at the cost of fencing and land holdings, it may not be appropriate in Indian conditions to use this method, although the preliminary studies yielded significant results. However, in North-eastern States this method can be followed in jhum cultivation. Non-lethal electric fencing as a barrier method was found to be cost effective and has limited extension value.

Other physical methods include burrow digging, smoking rat burrows with hay stack smoke etc.

Ultrasound devices

The sense of hearing among rodents is above 20 kHz thus extending well into ultrasonic range. Ultrasound devices are being used as deterrents to rodent immigration. However no convincing evidence was found them as effective against rodents. Similarly little scientific support was found for use of electromagnetic devices.

Botanical r repellents

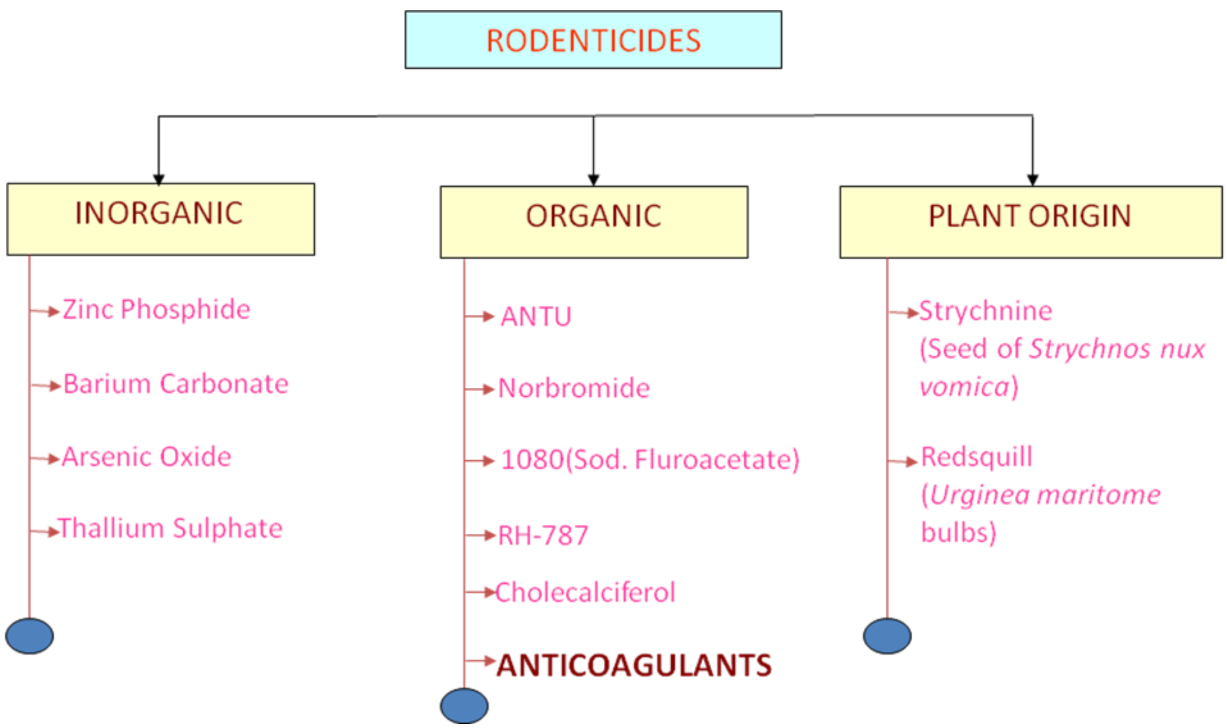
There is no effective chemical repellent available that is not also toxic. Although pheromones appear to be promising, lot of scientific work is required to identify, isolate and bring out the pheromones for extension purpose. Recently, a castor based repellent – Ecodon, exhibited significant repellent effect on *B. Bengalensis* in rice fields, when applied as granules or sprayed on the boundaries of rice crop. Rice tiller damage is less than 5% in treated fields, while untreated had more than 25% loss.

Trapping

Trapping is one of the oldest methods of animal control. A variety of traps can be used against rodents- live or snap. The efficacy of trapping, whether live or snap trap, depends on operational conditions of the trap, number of traps set, type of bait, place and time of placement.

Scientific literature has seldom proved trapping as effective method against rodents as a measure of reducing their numbers. However, they can be employed in controlling localized infestations effectively. Tanjor kitties, bamboo Palmyra traps are highly effective for localized infestations. They help in maintaining rodent numbers at a low level once they have been reduced by other methods. In a study during 1995, setting 17,900 Tanjore kitties (in 70 he.) yielded 4,029 rodents (25.33% trap success) in Kuruvai season and 4,176 rodents (24% trap success) in Samba and Thaladi season. About 70% of trapped rodents are *B. Bengalensis* and 30% are *Millardia meltada*. The trapping cost per rodent is about Rs 1.50.

RODENTICIDES AND THEIR MODE OF ACTION



ACUTE RODENTICIDES

Acute rodenticides are fast acting thereby bringing the mortality within 24 hours normally. Two inorganic chemicals come under the acute rodenticides. They are Barium corbanate and Zinc phosphide. Among zinc phosphide is the commonly used one.

1. Zinc phosphide

Zinc phosphide is greyish black, garlic like smelling powder, produced by direct combination on zinc and phosphorus. It is the most commonly used acute rodenticide in the world. It is insoluble in water and alcohol, stable when dry, but decomposes gradually in moist air. Acids decompose it quickly leading to the production of lethal gas Phosphine, which is very toxic to mammals. The acute oral toxicity of zinc phosphide to rodents are as follows: *Tatera indica* (35mg/kg), *Rattus rattus* (40.1 mg/kg), *Bandicota bengalensis* (25.0 mg/kg) and *Mus musculus* (250 mg/kg). This poison is widely used against field rat and mouse infestations. Baits with two per cent are generally recommended. Zinc phosphide when used as bait reacts with water and Hydrochloric Acid in the gastrointestinal tract of rodents to produce phosphine gas. This gas kills the animal through failure of cellular respiration, especially in nerve cells. If ingested accidentally, severe gastro-enteritis with nausea, vomiting and severe abdominal pain will result followed by cough, dyspnea, and pulmonary oedema. Severe poisoning may result in liver and kidney failure. Death is due to shock and peripheral circulatory failure

Generally rodenticides are used for mass scale rodent control campaigns. Application of rodenticides and environmental manipulation should be considered as complimentary to each other rather than alternative approaches. Amalgamation of various methods, as above, results in reduction in rodent damage in different situations.

SLOW ACTING RODENTICIDES (Anticoagulants)

As on now the slow acting rodenticides are all belonging to the category of anticoagulants, which act primarily, preventing the blood coagulation. The earlier anticoagulants, which have been introduced in the initial years, are first generation anticoagulants. However, with the advent of resistance among the residual populations, anticoagulants that are more potent have been developed. These are called second generation anticoagulants with added advantage of effective kill of even resistant populations with reduced quantify of poison baits.

Warfarin

Warfarin belongs to the first generation anticoagulant category and kills rodents after uptake of 4-5 daily doses of 0.2 mg/kg per day. Its acute toxicity is 173 mg/kg. It was extensively used for controlling rodents in storage. It is recommended at 0.025% a.i. in cereal baits and in liquid bait. However, warfarin is not available in market at present.

Bromadiolone

Bromadiolone is a second-generation anticoagulant and kills the resistant rodents. The acute oral toxicity is 3-5 mg/kg. It has no chronic toxicity. Single feeding of the baits also brings mortality of rodent population (40-60%) three days after the application. Hence, it is recommended in *'Pulsed baiting'* technique. It is formulated as concentrate powder (0.25 per cent) and as ready-to-use bait (0.005 per cent). It is recommended at 0.005 per cent a.i. in solid bait by mixing 1 part of the concentrate in 49 parts of bait mataerial for controlling rodents in storage and agricultural situations. Application in 10 paper packets gave significant results in field conditions. Under domestic situation usage in simple bait stations yielded good results. The ready-to-use cake is coated with thin layer of wax to protect the bait from weather. These cakes are recommended to use in in-accessible situations in field conditions.

RESPIRATORY POISONS

Aluminium phosphide 0.6 g. pellets are recommended for rodent burrow fumigation @ 2 pellets per burrow. This is a restricted rodenticide to be used under the supervision of technically competent persons. The pellets can be procured by the Government Departments directly from the manufacturers. The burrows of *B. bengalensis* can be effectively treated with this fumigant. One pellet per burrow will be effective to control *field mice.* The pellets release phosphine gas in the atmospheric conditions, which is lethal to the rodents inside the burrows. Due to this care is required to be taken to insert the pellets deep inside the rodent burrows and burrows are to be plugged to prevent leakage of the toxicant gas from the rodent burrows.

For 1 kg Bromadiolone :	960g cereal + 20g oil + 20 g bromadiolone bait concentrate (0.25%) mix thoroughly with the help of stick
For 1 kg of Zinc phosphide:	950g cereal + 25g oil + 25 g bromadiolone bait concentrate (2.5%) mix thoroughly with the help of stick

ANTICOAGULANT RODENTICIDES AND RESISTANCE IN RODENTS

Anticoagulant rodenticides were first discovered in the 1940 s and have since become the most widely used toxicants for commensal rodent control. Rodents poisoned with anticoagulants die from internal bleeding, the result of loss of the blood s clotting ability and damage to the capillaries. Prior to death, the animal exhibits increasing weakness due to blood loss, though appetite and body weight are not specifically affected. Because anticoagulant baits are slow in action (several days following the ingestion of a lethal dose), the target animal is unable to associate its illness with the bait eaten. Therefore, bait shyness does not occur. This delayed action also has a safety advantage because it provides time to administer the antidote (vitamin K1) to save pets, livestock, and people who may have accidentally ingested the bait.

The first anticoagulants (warfarin, pindone, diphacinone and clorophacinone), are commonly known as the first-generation anticoagulants or multiple-feed rodenticides. These compounds are chronic in their action, requiring multiple feedings over several days to a week or more to produce death. In order to achieve this multiple feeding, the bait must be made available on a continuous basis until the desired control is reached.

Where anticoagulants have been used over long periods of time at a particular location, there is an increased potential for a population to become somewhat resistant to the lethal effects of the baits. Resistance of rats to warfarin was first noted in Scotland in 1958, some years following its repeated use. Shortly thereafter, anticoagulant resistance was identified in both rats and house mice in other European countries. Rats and mice that are resistant to warfarin also show some resistance to all first generation anticoagulants, rendering control with these compounds less effective. Although relatively uncommon, a few instances of resistance have been reported in the United States.

Warfarin resistance led to the development of the second-generation anticoagulants, bromadiolone and brodifacoum. These compounds are much more potent than the first-generation anticoagulants, making them effective for the control of warfarin-resistant rats and mice. As one feeding can produce death if a sufficient amount of bait is consumed, they are often referred to as single-feed anticoagulants. In commensal situations where rodents are often marginal or reluctant feeders, these compounds can be extremely effective. The effects of these compounds are also cumulative and will result in death after several feedings of even small amounts. As in the case of all anticoagulants, death is delayed for several days following the ingestion of a lethal dose.

Where anticoagulant resistance is known or suspected, the use of first-generation anticoagulants should be avoided in favor of the second-generation anticoagulants or one of the non-anticoagulant rodenticides like bromethalin or cholecalciferol.

Because of their similarity in mode of action, all anticoagulant baits are used in a similar fashion. Label directions commonly instruct the user to "maintain a continuous supply of bait for 15 days or until feeding ceases", thus ensuring that the entire rodent population has ample opportunity to ingest a lethal dose of the bait. Anticoagulants have the same effect on nearly all warm-blooded animals, but the sensitivity to these toxicants varies among species. If misused, anticoagulant rodenticides can be lethal to nontarget animals such as dogs and cats. Additionally, residues of anticoagulants which are present in the bodies of dead or dying rodents can cause toxic effects to scavengers and predators. In general, however, the secondary poisoning hazard from anticoagulants is relatively low.

First-generation anticoagulants:

Warfarin: 3-(alpha-acetonylbenzyl)-4-hydroxycoumarin

Warfarin was the first marketed anticoagulant and therefore became the best known and most widely used. It has relatively limited sales today, due to the availability of more potent anticoagulants.

Pindone: 2-pivalyl-1,3-indandione

Pindone is also one of the early anticoagulants which is still available for use in commensal rodent control. Although regarded as slightly less effective than warfarin, it has some properties that resist insects and growth of mold. For optimal control using warfarin or pindone, bait must be available to rodents over a period of several days, so that there is no longer than 48 hours between feedings. Ideally, daily feedings should occur.

Chlorophacinone: 2-[(p-chlorophenyl)phenylacetyl]-1,3-indandione

Diphacinone:2-diphenylacetyl-1,3-indandione

Chlorophacinone and diphacinone are similar in potency and are significantly more toxic than the anticoagulant compounds developed earlier. Consequently, they are formulated at lower concentrations. Chlorophacinone and diphacinone may kill some rodents in a single feeding, but multiple feedings are needed to give adequate control of an entire population.

With these compounds, feeding does not always have to be on consecutive days. When anticoagulants are eaten daily, however, death may occur as early as the third or fourth day. For optimal lethal effects, several feedings should occur within a 10-day period with no longer than 48 hours between feedings.

Second-generation anticoagulants:

Brodifacoum: 3-[3-(4'bromo[1,1'-biphenyl]-4-yl)-1,2,3,4,-tetrahydro-1-naphalenyl] -4-hydroxy-2H-1-benzophyran-2-one

Brodifacoum is the most potent rodenticide currently available for commensal rodents. It is available in 0.005% pellet formulations and in wax blocks. Because of its acute toxicity, a lethal dose can be obtained in a single feeding, although death is delayed for 4 or 5 days.

Bromadiolone: 3-[3-(4 bromo[1,1 biphenyl]-4-yl)-3-hydroxy-1-phenylpropyl] -4-hydroxy-2H-1-benzopyran-2-one

Bromadiolone is not quite as toxic to rodents as brodifacoum but can result in the same level of control. It is available in 0.005% pellet formulations and in wax blocks.

Anticoagulant Bait Formulations

Most of the anticoagulant baits used today are commercial ready-to-use baits in grain, pelleted or wax form. Grain and pelleted anticoagulant baits are used extensively in tamper-resistant bait boxes or stations for a permanent baiting program for Norway rats and house mice. They may not be effective on roof rats, however, because of their placement. Bait stations are difficult to place for roof rat control because of the rodents overhead traveling habits.

Paraffin-type bait blocks provide an alternative to bait stations containing pelleted or loose cereal bait. If permitted by the label, bait blocks can be placed or fastened in locations where bait boxes with loose grain or pelleted bait would be difficult to place, and where they are readily accessible to roof rats.

Generally, roof rats are less susceptible to first-generation anticoagulant rodenticides than Norway rats and a few more feedings are necessary to produce death. This is less significant with the second-generation anticoagulants. For best results, several baits should be tried to find out which one rats consume most. House mice are susceptible to all of the various anticoagulant rodenticides, but they are generally less sensitive (often far less sensitive) to the active ingredients than are Norway or roof rats. It usually requires a few more feedings to produce death with the first-generation anticoagulants than with the second-generation anticoagulants.

Anticoagulant Bait Failure

Resistance is only one (and probably the least likely) reason for failure in the control of rodents with anticoagulant baits. Control with baits that are highly accepted may fail for one or more of the following reasons:

- Too short a period of bait exposure.
- Insufficient bait and insufficient replenishment of bait (none remains from one baiting to the next).
- Too few bait stations and/or too far apart. In some situations, stations may have to be within 20 to 30 feet (7 to 10 m) of one another.
- Too small a control area, permitting rodents to move in from untreated adjacent areas.
- Genetic resistance to the anticoagulant. Although this is unlikely, it should be suspected if about the same amount of bait is taken for a number of weeks.

Control with anticoagulant baits that are poorly accepted may fail for one or more of the following reasons:

- Poor bait choice, or bait is formulated improperly. Other more attractive foods are available to rodents.
- Improperly placed bait stations. Other foods are more convenient to rodents.
- Abundance of other food choices.
- Tainted bait: the bait has become moldy, rancid, insect-infested, or contaminated with other material that reduces acceptance. Discard old bait periodically, and replace it with fresh bait.

Occasionally, rodents accept bait well and an initial population reduction is successful. Then bait acceptance appears to stop although some rodents remain. In such instances it is likely that the remaining rodents never accepted the bait either because of its formulation or placement. The best strategy is then to switch to a different bait formulation, place baits at different locations, and/ or use other control methods such as traps.

Non-anticoagulant Rodenticides

The older rodenticides, formally referred to as the acute toxicants (e.g., arsenic, red squill and phosphorus) are either no longer registered or of little importance in commensal rodent control. Newer rodenticides are much more effective and have resulted in the phasing out of these older materials over the last 20 years.

At present there are three non-anticoagulant rodenticides - zinc phosphide, cholecalciferol (Vitamin D3) and bromethalin - registered and available for commensal rodent control. Since none of these are anticoagulants, all can be used to control anticoagulant resistant rodent populations.

Of these active ingredients, bromethalin and cholecalciferol are formulated to serve as chronic rodenticides, applied so that rodents will have the opportunity to feed on the baits one or more times over the period of one to several days. Because they are slow-acting in comparison to zinc phosphide, bait shyness is not usually a problem, nor is prebaiting necessary to get good control in most situations. Zinc phosphide differs in that prebaiting (offering rodents similar but non-toxic bait prior to applying the toxicant-treated bait) is recommended to increase bait acceptance. Zinc phosphide is not designed to be left available to rodents for more than a few days, as continued exposure is likely to result in bait shyness within the population.

Non-anticoagulant rodenticides, particularly zinc phosphide, remain useful tools to achieve rapid reductions in rodent populations. When population levels are high, the cost of baiting with these materials may be lower than for the anticoagulants.

Bromethalin N-methyl-2,4-dinitro-N-(2,4,6-tribromophenyl)-6-(trifluoromethyl) benzenamine

Bromethalin is a single-dose rodenticide that causes central nervous system depression and paralysis, leading to death in 2 to 4 days. Bait should be renewed at intervals of several days. Continuous bait availability (as with anticoagulants) is not required, but bait needs to be present long enough to allow all animals in the area to feed. The amount of bait needed is usually about one-third that used with anticoagulants, since an animal ingesting a lethal dose does not feed again. This effect is unlike that of anticoagulants, in which rodents continue to consume bait after they have ingested a lethal dose. Bait shyness has not been reported.

Cholecalciferol (Vitamin D3) 9,10-Seocholesta-5,7,10(19)-trein-3 betaol

Cholecalciferol is a single-dose or multiple-dose rodenticide that causes mobilization of calcium from the bone matrix to plasma and death from hypercalcemia. Time to death is 3 to 4 days after ingestion of a lethal dose. As the toxicant is slow-acting, bait shyness apparently does not occur. As with Bromethalin, once a rodent consumes a lethal dose, all food intake ceases.

Zinc phosphide

Zinc phosphide is a dark gray powder, insoluble in water, that has been used extensively in the control of rodents. When zinc phosphide comes into contact with dilute acids in the stomach, phosphine (PH_3) is released. It is this substance that probably causes death. Rats and mice that ingest lethal amounts of bait usually succumb overnight with terminal symptoms of convulsions, paralysis, coma, and death from asphyxia. They typically die in a prone position with their legs and tails outstretched. Because zinc phosphide is not stored in muscle or other tissues of poisoned animals, there is no secondary poisoning with this rodenticide. The bait, however, remains toxic up to several days in the gut of a dead rodent. Other animals can be poisoned if they eat enough of the gut content of rodents recently killed with zinc phosphide.

Zinc phosphide is available in ready-to-use dry baits and also in concentrates for use by persons trained in rodent control who may wish to prepare their own baits. Its strong garlic-like odor appears to be attractive to rodents that are not bait-shy and apparently makes the bait unattractive to some other animals. Bait shyness can be a problem; so prebaiting is recommended or necessary for achieving good bait acceptance.

Integrated Rodent Pest Management

Control strategies:

1. Harbourage reduction:

Garbage, junk and other hiding and nesting materials provide harbourage to rodents in stores and godowns. The periodic removal of rubbish and maintenance of good hygiene/sanitation around stores/godowns discourage rodents in those premises. It also means removing spilled grains and food scraps left over from the feeding pets or domestic animals.

2. Proofing:

Proofing of storage structures against rodent with appropriate techniques is the first line of defense. In 1965 Save Grain Campaign Programme was launched in India by the Department of Food, Government of India to prevent losses in food grains in storage. It suggested certain improvements to reduce losses in traditional storage structures by adoption of rat proof techniques, such as:

a. A concrete or reinforced brick floor as the base for straw roped structures
b. A wooden platform with metallic cones (indoor) or a masionary plat form with GI sheet roofing (Out door) for bamboo storage structures
c. Nailing with metallic sheet at bottom to wooden storage structures
Some other improved storage structures like metallic drums were also suggested.

3. Mechanical

The most common method used is trapping. The local available traps should place on the paths where rodents move frequently. Success of traps depends on its proper placement and selection of bait material. Different types of sticky/glue traps are also made available for catching rats and mice (PRAKASH, 1990). Fumigation of rodent burrows and use of ultrasonic devices are the other methods.

4. Chemical control:

Rodenticides are most commonly used. Among the rodenticides, the anticoagulants are very effective for control of rats in houses/godowns/warehouses than the acute rodenticide, zinc phosphide. Of the anticoagulants, the single dose anti coagulants like bromadiolone, broadifacoum and flocoumafen are most effective than multi dose anticoagulants and are widely used. The anticoagulants are available in the form of solid or water soluble baits or ready to use formulation.

Dry bait preparation:

For preparation of 500 g solid bait, take 450 g (Four tea cup full) of crushed cereal baits of local preference, 15 g (3 tea spoonful) of sugar, 10 g (2 tea spoonful of oil and mix all these thoroughly and then add 25 g (5 tea spoonful) of anticoagulant and again mix it thoroughly.

Water soluble bait (Liquid bait)

For the preparation of 500 ml of anticoagulant bait, take 25 g (5 tea spoonful) of water soluble anticoagulant concentrate and dissolve it in 500 ml (3 tea cup full) of water.

Placement of bait

- Select the baiting points where the rats visit frequently.
- A quantity of 50-100 g of prepared dry bait/ready to use bait should be placed in bait stations and keep at the points selected.
- The liquid bait of about 150 ml poured in to a shallow container should be placed at the selected points.
- Inspect the baiting points daily and change the points, if the baits are not consumed or replace the bait if they consume.
- Keep the baits continuously for about 3 weeks for successful results. Later one or more permanent baiting points may be retained in order to control re-infestation.

Fumigation

Fumigation of rodent burrows with aluminium phosphide @ 3 g per burrow and the burrows must be closed with wet mud after the application. Check for re-opened burrows next day. As the aluminium phosphide was highly toxic, it should be done under technical supervision.

Integrated rodent pest management / Strategies for the management of Rodents in rice:

Although, rodent control in rice fields has been practiced for centuries, the problem still remains an acute one because of the haphazard strategy which aimed at removing pests during out breaks. Hence, it is important to recognize rodent control is an ecological operation since; it is the regulation of populations and not the destruction of individuals. Rat control can be best achieved by being aware of the rat's basic needs such as food and shelter and then limiting those factors that favour rats. There are several cultural practices that can be used to limit rat population growth.

Habitat management:

- Removal of weeds, both within the crop and along the bunds has an important limiting effect on rat population. The clearance of over grown weeds and bushes in surrounding areas of rice fields also limits the number of rodents by reducing the source of food and shelter during the lean periods and increasing the chances to expose them to predators.
- Reduce the size and number of bunds to limit burrowing sites and places for weeds to grow.
- Synchronized planting of rice with varieties having same duration over wider areas would act as natural check to rat population growth as the breeding in rats is linked with the growth phases of the rice crop. The availability of rice crop in reproductive stages for longer periods will lead to extended breeding and very high rat infestation levels.
- Proper water management in rice fields may prevent rodent damage to germinating seeds in nursery.
- Complete removal or destroying of rice stubbles after harvest will limits the rodent population, which will otherwise provide food during lean period.

Physical and Mechanical:

Trapping:

Different types of snap traps made of bamboo are being used for snap trapping in Andhra Pradesh (Butta), Tamilnadu (Tanjore kitty) and North Eastern states (Urang or Arrow trap) by farmers and tribal people. Comparative efficacy of these three traps indicated that Butta was more effective than the other two kinds of traps (ANONYMOUS, 2003). These traps provide fairly good results after poison control. Rodent control through trapping alone will be costly and one cannot manage rodent population over large areas.

Fumigation:

Rodents damaging rice crop are living in burrows. Control of these rodents with natural smoke is an age-old practice in India. The simple principle involved in this is by fumigating the burrows with smoke, the rodents inside the burrow will die due to suffocation. For this purpose plant protection equipment called "Burrow Fumigator" was developed at A.P. Rice Research Institute, Maruteru (RANGA REDDY et al., 1992) which is being very extensively used by the delta farmers of Andhra Pradesh. Its efficacy was evaluated compared to aluminum phosphide (VASANTHA BHANU et al., 2004) and reported 92% rodent mortality with Burrow Fumigator and 97% with aluminium phosphide (Table 3).

Chemical control

The control of rodents by using rodenticides is the most common practice. It is better to undertake rodent control through poison baiting during lean periods when the rodent population will be at minimum. There are two groups of rodenticides commonly used in rodent control. 1. Acute rodenticides like zinc phosphide 2. Chronic rodenticides like Bromadiolone. They are used at 2% in cereal baits.

Advantages of zinc phosphide

1. Quick kill
2. Small quantity of chemical is required
3. Single feeding is enough
4. Population will be brought down immediately

Disadvantages of zinc phosphide

1. Necessity of pre baiting
2. Low killing around 40-50%
3. Induce bait shyness
4. Toxic to non target species
5. Chances of secondary poison are more

Compared with acute rodenticides, the chronic anticoagulant rodenticides are less hazardous to humans and pet animals. The first generation anticoagulant rodenticides are effective only with several feedings, which increases the cost of operation. In order to overcome these limitations with first generation anticoagulant rodenticides some anticoagulants now being introduced which require only a single feeding, called second-generation anticoagulants.

Baits and Baiting:

Preparation and placement of bait are the most important aspects for an effective chemical control strategy. While preparation of bait, the proportion of the toxicant to bait should be maintained properly, otherwise, it leads to bait shyness (sublethal doses) or repellency (heavy doses). Similarly the placement. The bait should be placed either in the burrows or in bait containers/bait stations.

Burrow baiting: This method is advisable in field conditions where clear rodent burrow are visible and placed the bait packets deep inside the live burrow.

Bait Stations: This method is advisable in field conditions where two or more rodent species are inter associated with different micro habitats. The anticoagulant treated loose bait placed in a suitable bait stations @ five/ha is made available to rodents from transplanting to harvest or until the consumption ceases. Several types of bait containers have been used as bait stations viz., coconut husks, hallow bamboo pieces, coconut shells, cement channels etc.

Impact of Rodent control on community basis and economics:

Even though, the effective tactics to manage rodents are available, the problem of rodents continues to persist due to their improper implementation by farmers. The major reasons for its failure is non-adoption of long lasting efforts, untimely adoption of control measures at individual levels and the absence of community approach. To overcome these problems, an on-farm research was carried out at village level for two successive seasons, under the supervision of the technical experts. The participating farmers were also trained about the technologies of the rodent control. At tillering stage of the crop growth poison baiting with bromadiolone 0.005% was implemented in the entire village. Pre and post treatment data on number of burrows and percent tiller damage was collected. The results indicated that the mean percent reduction of live burrows was 49.68% and tiller damage was 61.89 %. The estimated yield loss before and after intervention was worked our as per TUAZON (1979). This intervention reduced the yield loss of 2.52 % which was equal to 75 kgs of paddy/acre. The monetory benefit accrued was Rs.420/- per acre with the cost benefit ratio of 1: 44.54.

Timing of Rodent control:

Based on the data on population dynamics, breeding behaviour of rodents, particularly, *B.bengalensis* in rice in relation to crop cycle and seasons, it was concluded that it is advantageous to initiate rodent control operations during the lean period with the following reasons:

1. Rodents accept easily the poison bait placed in their burrows as the food and shelter are scarce in crop lands during lean period (April-May).
2. Control of non-breeding population generally observed during lean period, breaking the natural cyclicity of rodents.
3. Lean period treatment prevents population explosion during the cropping season.
4. In the absence of lean period treatment, the effective period for poison baiting in crop season is tillering to primordial initiation stage. This is because; rodents avoid poison baits in preference to rice crop at subsequent reproductive phase.

The observations made at this institute on the consumption of bait at different growth phases of the crop revealed that the maximum bait consumption was observed from tillering to panicle initiation (Table 4). The quantity of poison bait is an indication of the effective period for baiting and its acceptance.

Based on the merits and demerits of the above individual tactics, the bio-ecology of the rodents and the crop stages, a seasonal calendar for rodent management in rice by integrating all the possible control methods was developed (Fig 3).

Rodent control options

A. EFFECTIVE PERIOD

1. Cultural practices such as:

- ❖ Removal of weeds on the field bunds and within the field.
- ❖ Reduction in bund size and number
- ❖ Synchronous planting

2. Traps @ 20/ acre installed from field preparation to early tillering stage.

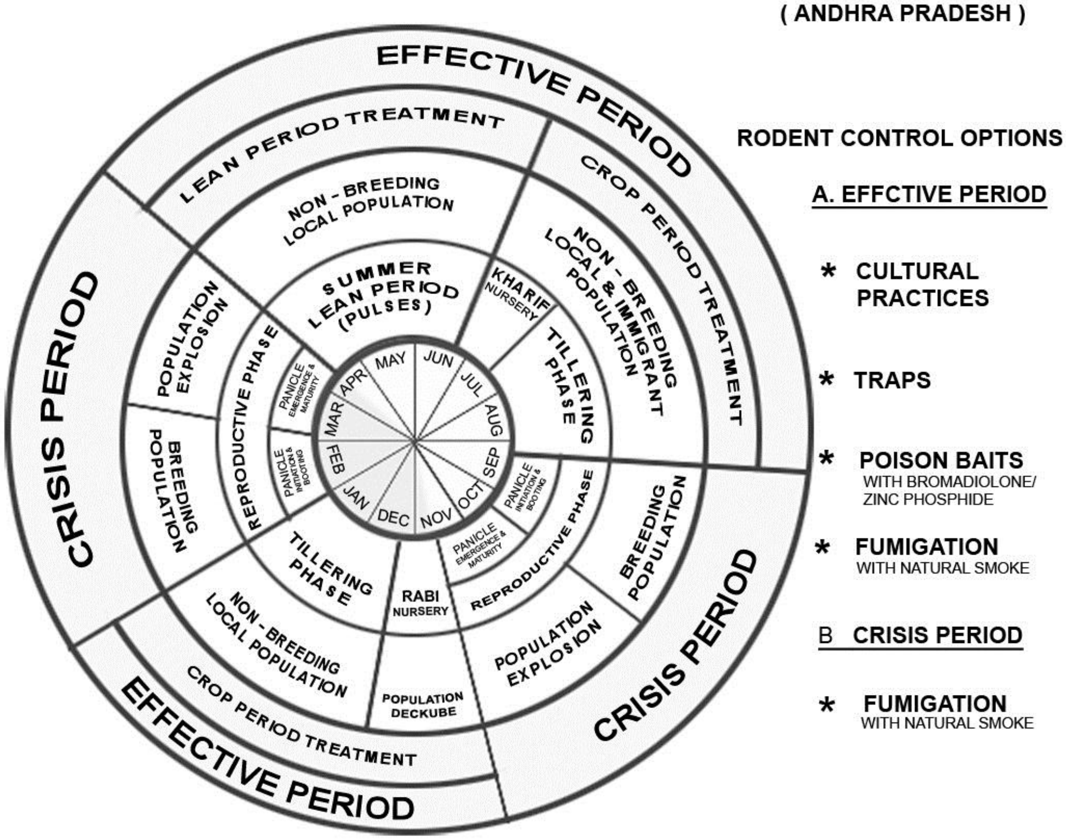
3. Poison baiting either with bromadiolone/ zinc phosphide preferably during lean period or tillering stage.

Action plan for bromadiolone baiting:

Day 1: Identify live burrows and place 10 g of bromadiolone (0.005 %) bait (96 parts of rice brokens + 2 parts of edible oil + 2 parts of bromadiolone concentrate) inside the burrow.

Day 11: Repeat bromadiolone (0.005 %) baiting in residual burrows.

FIG.3 SEASONAL CALENDAR FOR RODENT MANAGEMENT IN RICE IN GODAVARI DELTA (ANDHRA PRADESH)



Poison baiting with zinc phosphide should be adopted in case of high rodent population levels to achieve quick results.

Action plan for zinc phosphide baiting:

Day 1: Identify live burrows and place 20 g of pre bait material inside the burrow .

Day 2: Repeat the same

Day 3: Place 10 g of zinc phosphide poison bait (96 parts of rice brokens + 2 parts of edible oil + 2 parts of zinc phosphide) inside the burrows in packets**.**

Day 4: Collect the dead rats and burry them

Day 5: To manage residual rodent population trapping should be adopted.

4. Fumigation with natural smoke.

B. CRISIS PERIOD: Fumigation with natural smoke.

The effectiveness of rodent control operations depends up on the people responsible for their implementation, being aware of the problems involved, their motivation and their interest in achieving success. The tools required are (a) regular monitoring (b) well trained operators and (c) access to labour and materials when they are needed.