PRINCIPLES AND CONCEPTS 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

1.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

2. 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 :

1.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.

2. 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.

3. 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 (as a sucking pest)	4 adults/leaf
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.

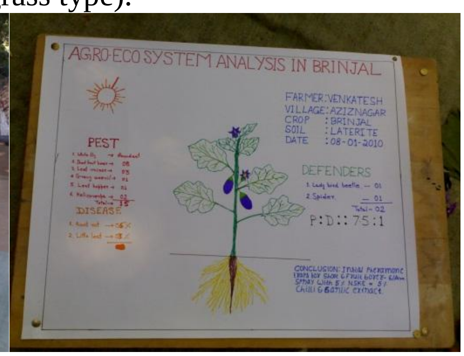
Plant: Find the shady place to sit as a group. Each group should sit together in a circle, with pencils, crayons data from each of the field activities (IPM), local package and other studies), and the drawing of the field ecosystem from the previous weeks.

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 three leaves from the plant, one taken from the top, one from the middle and one from the bottom 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.

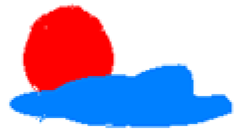
    Questions:
    a) Describe the general condition of the plant.
    b) What do farmers think are the most important factors affecting their crops at this stage ?
    c) What, if any, measure should be taken ?

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



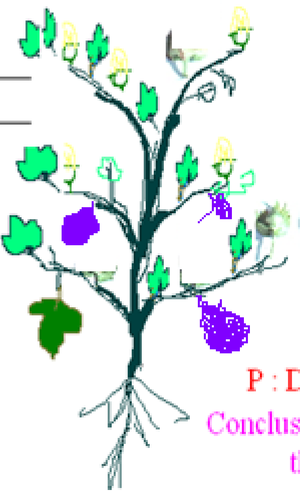
General Observation
Village :
Farmer :
Variety :
Stage :

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

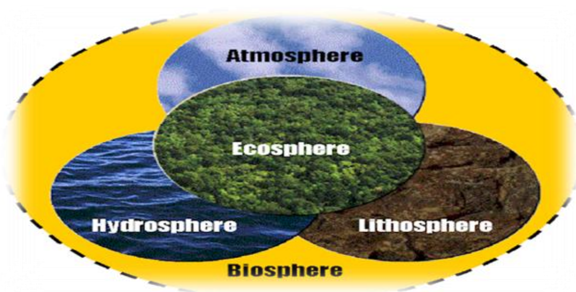
- ☐ 1866 Ernst Haeckel: the comprehensive science of the relationship of the organism to the environment
- ☐ 1927 Charles Elton: Scientific natural history
- ☐ 1963 E. P. Odum: The study of the structure and function of nature
- ☐ 1972 C. J. Krebs: The scientific study of the interactions that determine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

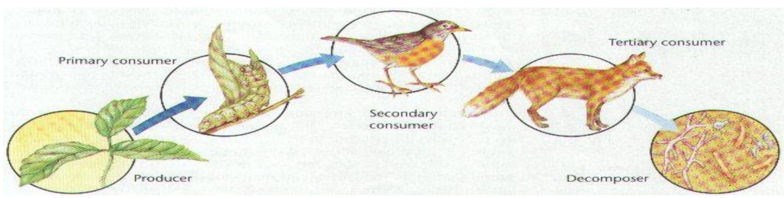
1. Autotrophs
2. Heterotrophs

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



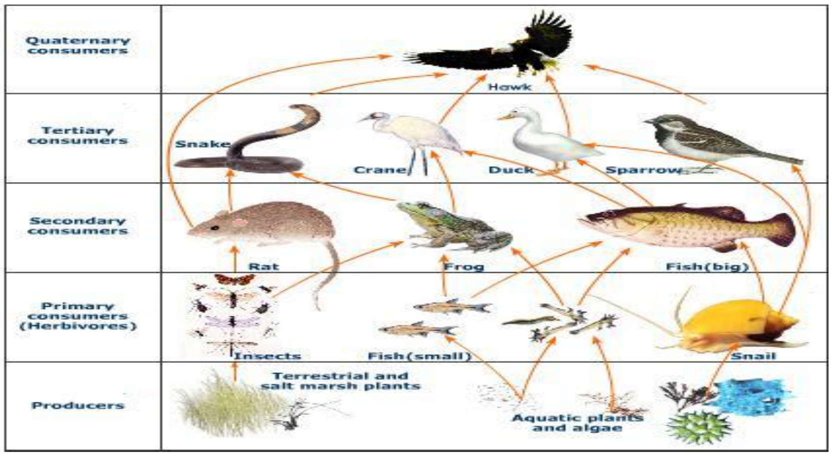
- ✓ Producers - organisms which can make their own energy from carbon dioxide and water using sunlight for energy (plants)
- ✓ *Primary consumer* - organisms which eat producers (herbivores)
- ✓ *Secondary consumers* - organisms which eat primary consumers (carnivores)
- ✓ *Tertiary consumers* - organisms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

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

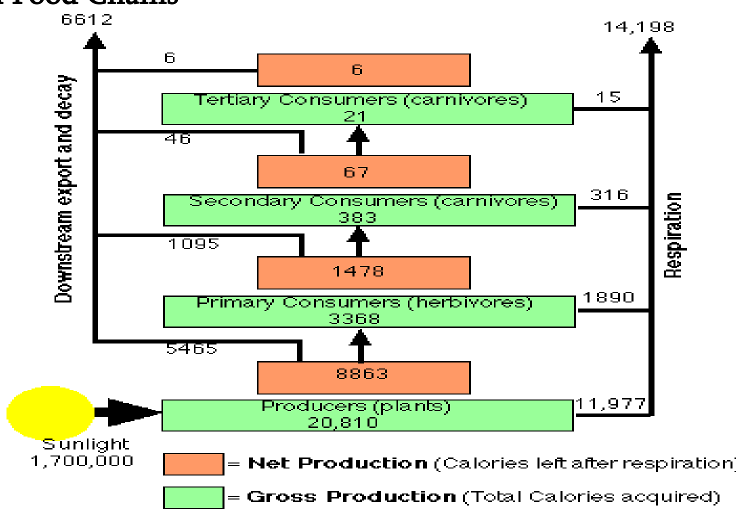
Producers are always on the first trophic level.

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

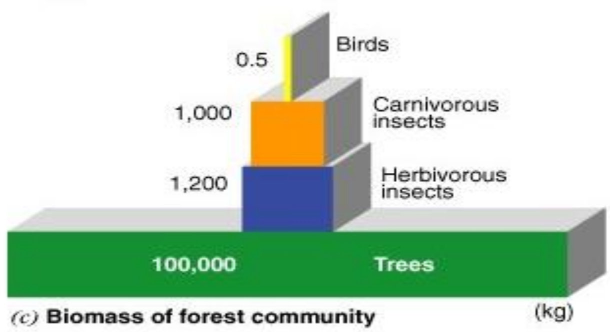


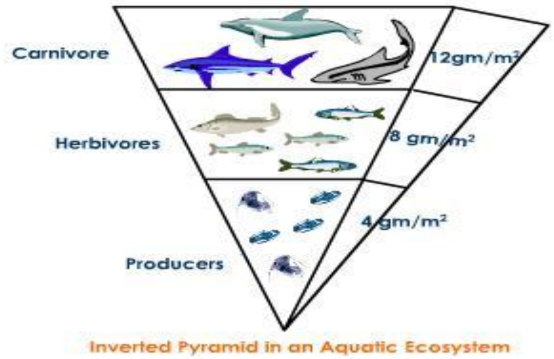
Ecological pyramid
An ecological pyramid is a graphical representation designed to show the biomass or biomass productivity at each trophic level in a given ecosystem.

1 .Pyramid of biomass
2 .Pyramid of Energy
3 .Pyramid of numbers

1 .Pyramid of biomass

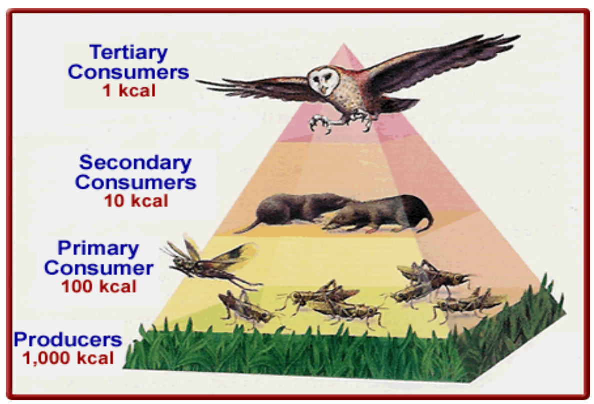
Typical units for a biomass pyramid could be grams per meter^2, or calories per meter^2.



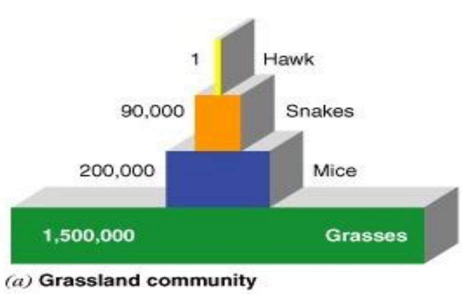


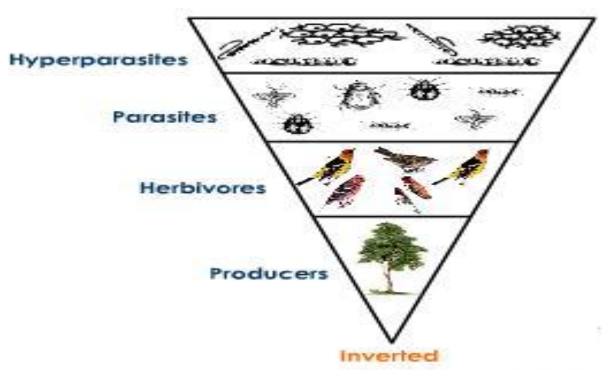
2 . Pyramid of Energy

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

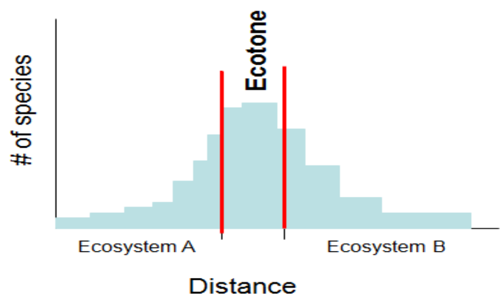
Habitat

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:

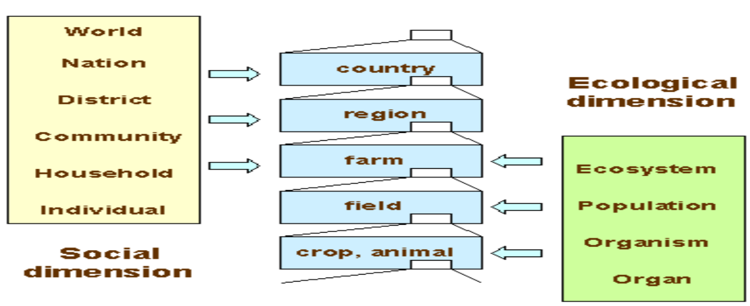
1.Gaseous cycles– Co2, N2,

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, actinomycetes)	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.

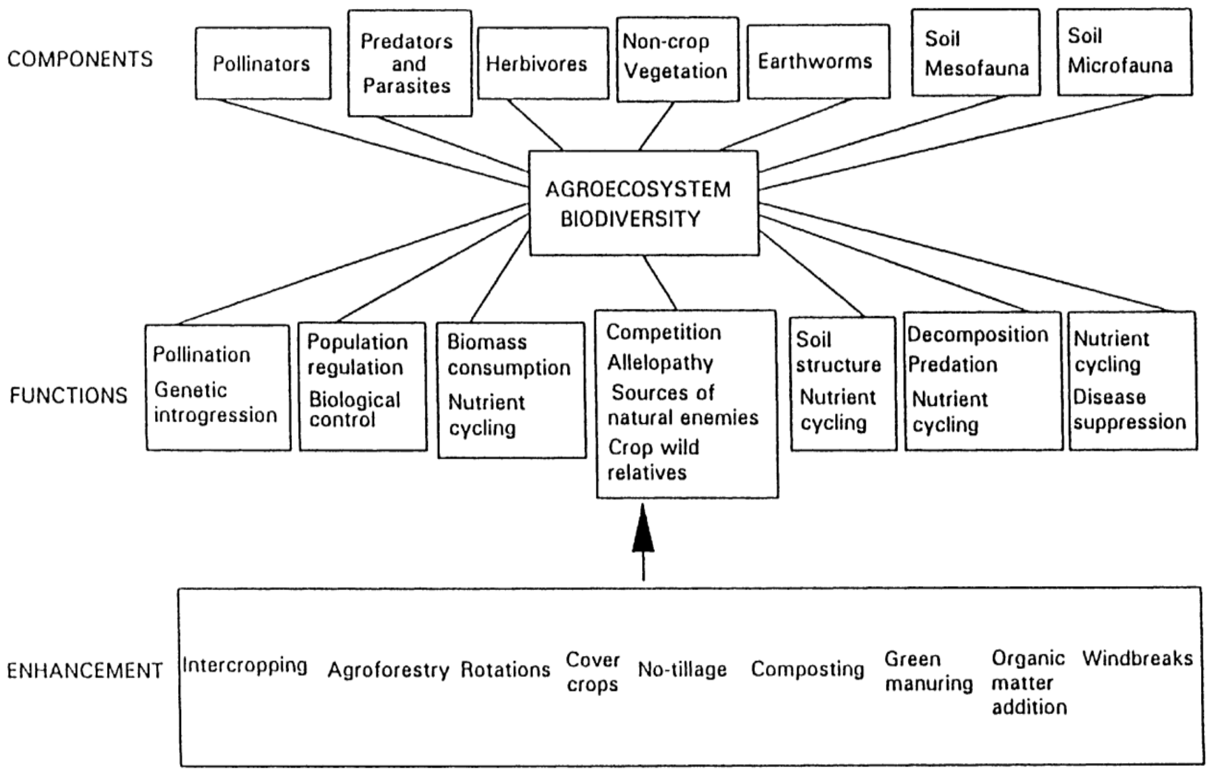
3. The intensity of management.
4. The extent of the isolation of the agroecosystem from natural vegetation.

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.

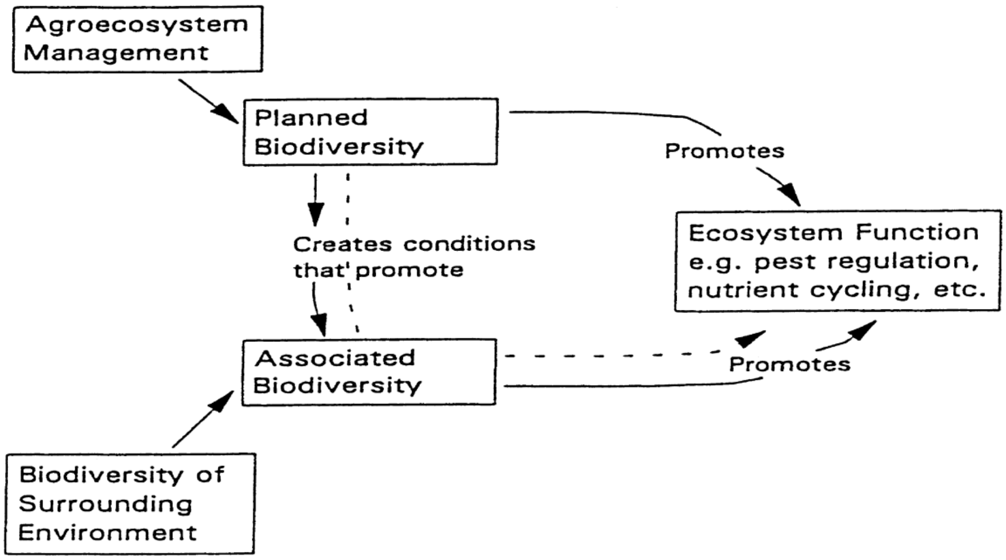
Productive biota: crops, trees and animals chosen by farmers which play a determining role in the diversity and complexity of the agroecosystem.

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

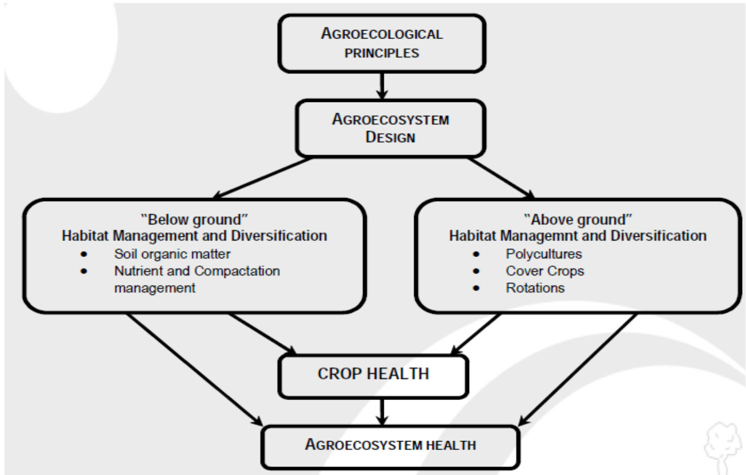


The relationship between planned biodiversity and associated and how the two promote ecosystem function

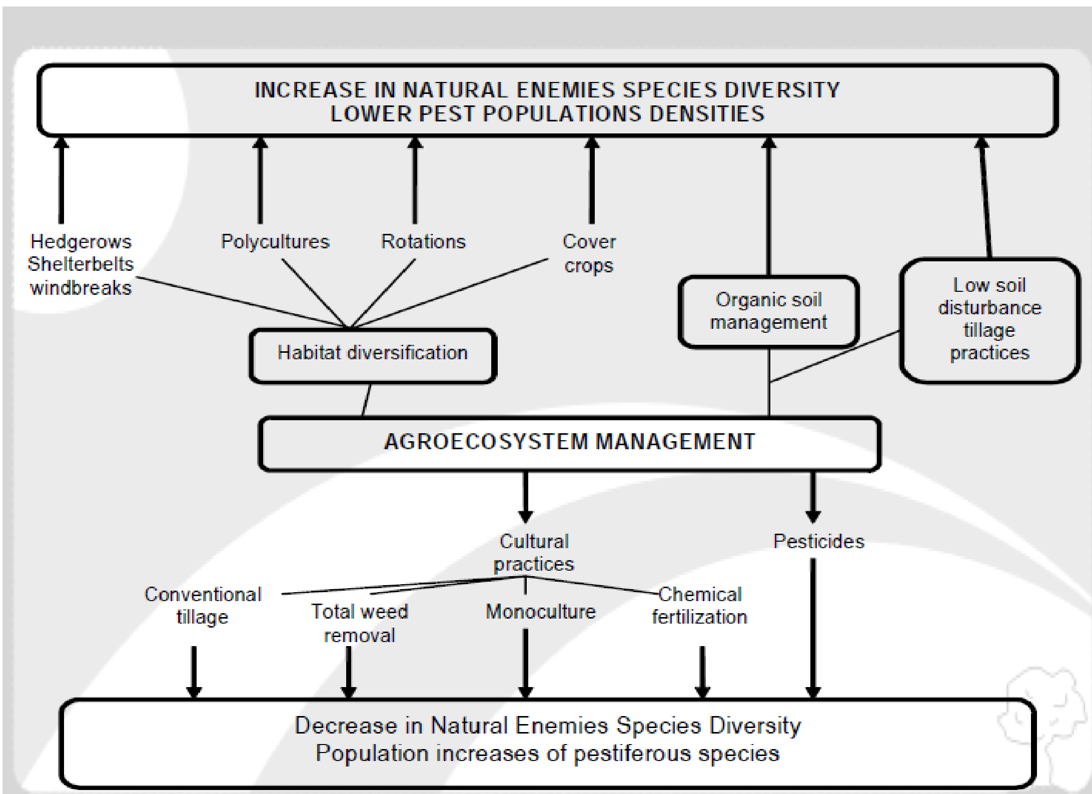
Agroecology provides basic ecological principles on how to study, design and manage agroecosystems that are productive, enduring and natural resource conserving. Agroecosystems can be manipulated to improve production andproduce more sustainably, with fewer negative environmental and social impacts and 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"

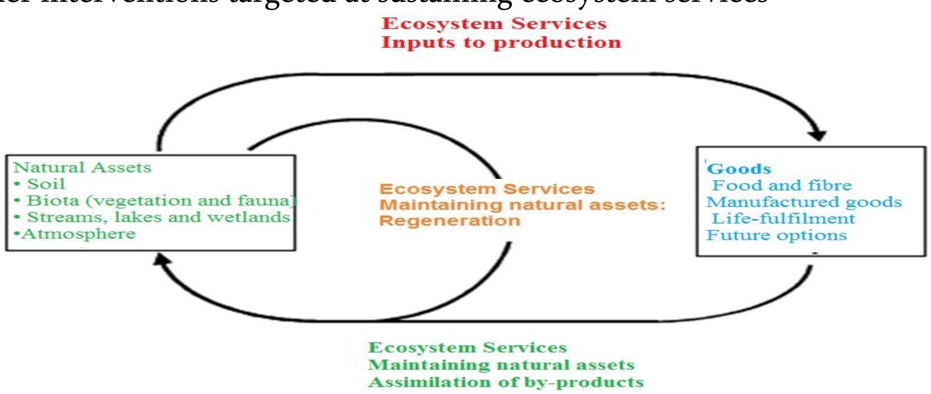
Ecosystem Services Approach

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, silk)	Non-wood and non-fuel based fibers extracted from the natural environment for a variety of uses	Textiles Cordage (twine, rope)
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	Lakes serve as a sink for industrial emissions of sulfur Compounds

		from the atmosphere	
Climate regulation	Global	Influence ecosystems have on the global climate by emitting greenhouse gases or aerosols to the atmosphere	Forests capture and store carbon dioxide , Cattle and rice paddies emit methane
	Regiona l 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	Recreational pleasure people derive from	Hiking, camping and bird

ecotourism	natural or cultivated ecosystems	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

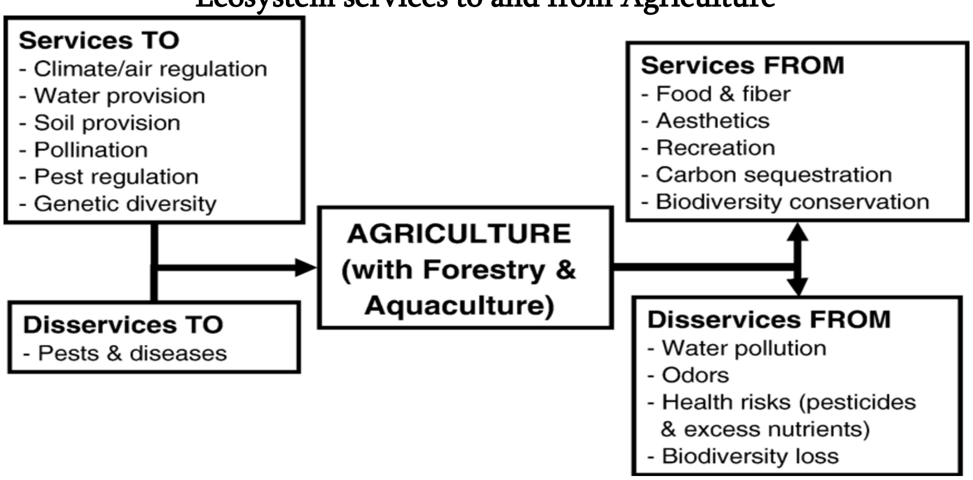
- ☐ (a) Agriculture can also be a source of disservices, including loss of biodiversity, agrochemical contamination and sedimentation of waterways, pesticide poisoning of non - target organisms, and emissions of greenhouse gases and pollutants.
- ☐ Nutrient cycling and pollution- From the local scale 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



Pest Resistance to Pesticides

Controlling Pests with Pesticides

Humans have been controlling or attempting to control insect and other arthropod pests, plant pathogens, weeds, rodents, and other vertebrate pests for thousands of years. However, it has been only within the last 50 years that significant progress has been made in controlling pests of humans and our food, fiber, animals, and the structures in which we live and work. This significant advance has occurred because of synthetic (man-made) pesticides, including insecticides, herbicides, fungicides, rodenticides, and algicides. Early successes with the first pesticides, such as DDT, came swiftly. Was the war against pests won so easily? Very soon after the rapid and astounding victories over mosquitoes and other biting flies, house flies, lice, and agricultural pests such as scale insects, a decline in the effectiveness of these new chemical weapons was observed. Application rates (ie., amounts used) were increased to regain the initial levels of control. However, the levels of control seemed to decline even more rapidly. The reduced levels of control, and eventual control failure in many instances, was found to be due to resistance of the pests to these chemicals.

What Is Pesticide Resistance?

Pesticide resistance is a genetically based phenomenon. Resistance occurs when a pest population— insects, for instance— is exposed to a pesticide. When this happens, not all insects are killed. Those individuals that survive frequently have done so because they are genetically predisposed to be resistant to the pesticide. Repeated applications and higher rates of the insecticide will kill increasing numbers of individuals, but some resistant insects will survive. The offspring of these survivors will carry the genetic makeup of their parents. These offspring, many of which will inherit the ability to survive the exposure to the insecticide, will become a greater proportion with each succeeding generation of the population.

Because of the rapid reproductive rate of many pests — a generation of many insects can take place in a few weeks — many generations can be produced in a single season or year. It’s easy to see that repeated applications of an insecticide will quickly eliminate all susceptible insects in the population, essentially selecting out those individuals that are resistant. In a short period the entire population of insects will be resistant. The more times a population is exposed to a pesticide, especially a broad-spectrum pesticide, the more quickly resistance will develop. Resistance develops in a similar manner in other pests, such as plant disease agents, weeds, and rodents. Ironically, to produce a resistant population one must start with a pesticide that initially gives very good control.

The Pesticide Resistance Problem

Today, pests that were once major threats to human health and agriculture but that were brought under control by pesticides are on the rebound. Mosquitoes that are capable of transmitting malaria are now resistant to virtually all pesticides used against them. This problem is compounded because the organisms that cause malaria have also become resistant to drugs used to treat the disease in humans. Many populationsof the corn earworm, which attacks many agricultural crops worldwide including corn, cotton, tomatoes, tobacco, and peanuts, are resistant to multiple pesticides.

Because many generations of some pests can develop in a single year, it is easy to see how resistance can develop so quickly in so many pest species. Recent studies indicate there are now over 500 species of insects and mites resistant to pesticides. Over 270 weed species, over 150 plant pathogens, and about a half dozen species of rats are resistant to pesticides that once controlled them.

Multiple resistance—resistance to more than one pesticide and to pesticides in more than one chemical class—is increasing rapidly. There are over 1,000 insect/insecticide resistance combinations, and at least 17 species of insects that are resistant to all major classes of insecticides.

Pesticides should not be considered the sole or even the primary solution to a pest problem. However, pesticides are frequently an integral part of a pest management program. Pesticide resistance dramatically lessens our ability to bring pest numbers below damaging levels in such a program.

Combatting Resistance

After a pest species develops resistance to a particular pesticide, how do you control it? One method is to use a different pesticide, especially one in a different chemical class or family of pesticides that has a different mode of action against the pest. Of course, the ability to use other pesticides in order to avoid or delay the development of resistance in pest populations hinges on the availability of an adequate supply of pesticides with differing modes of action. This method is perhaps not the best solution, but it allows a pest to be controlled until other management strategies can be developed and brought to bear against the pest. These strategies often include the use of pesticides, but used less often and sometimes at reduced application rates.

The Decreasing Availability of Pesticides

More and more pest species are becoming resistant to pesticides at an increasing rate. For many reasons, the availability of pesticidal products that can be used in rotation against pests is decreasing. The costs of developing a pesticide(i.e., the cost of research and testing, product development, etc.) are significant. Millions of dollars are spent on chemicals that may never become marketable products. Regulatory actions have affected pesticide availability. The U.S. Environmental Protection Agency has banned and restricted many pesticides in the past two decades.

Another factor in the decreasing availability of pesticides, especially from the supply of existing pesticides, is the EPA’s reregistration of pesticides. This reregistration program often requires additional testing of pesticides to determine if their use would possibly endanger the health of humans and our environment. It is difficult to argue with the basic rationale of those requirements. However, the cost of complying with EPA’s reregistration requirements for testing, plus the subsequent reregistration fees, is having a heavy impact on the current and future availability of pesticides. Many pesticide manufacturers are simply declining to reregister their products because the reregistration costs will severely reduce or eliminate potential profits from future product sales. More important, many individual active ingredients are already lost. Between pesticide cancellations and the reregistration process, whole classes of active ingredients are at risk of being lost from future use.

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 16th century and Potato was introduced into India in the early 17th 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 15th 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 17th century it was consumed as supplementary food. By early 18th 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

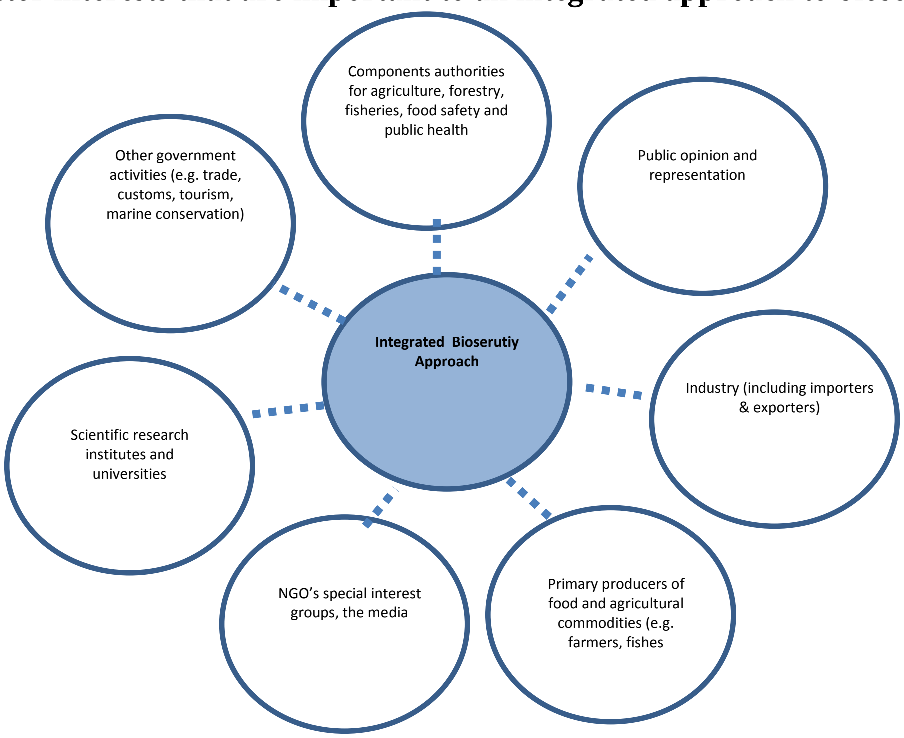
Basic Concepts of Biosecurity

- 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

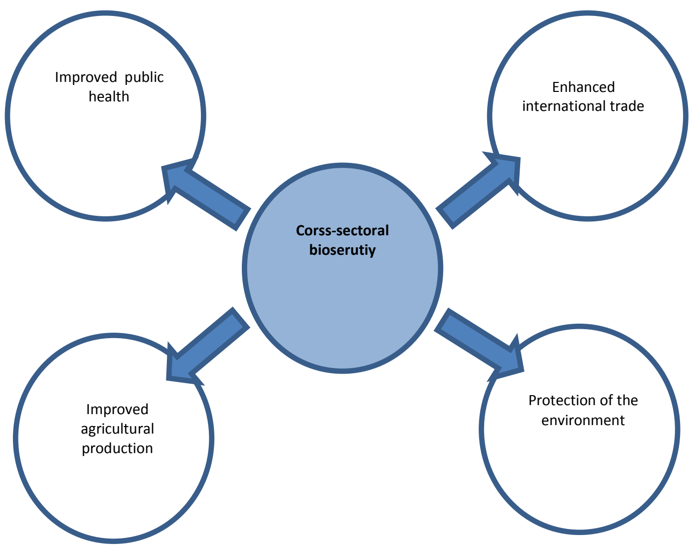
- In addition to the standards and related texts developed by the CAC (*Codex Alimentarius*), the OIE and the CPM, several other international **legal instruments, agreements and texts** are relevant to **biosecurity**.
- They are:
  - SPS (Sanitary and Phytosanitary)Agreement
  - TBT (Technical Barriers 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.

AN INTRODUCTION TO PLANT QUARANTINE

Man even in nomadic period carried with him the required seeds and plants wherever he moved. This practice is still continuing in the civilized settlements of mankind. As a consequence, many plant types have moved from their centers of origin, to an entirely new regions / continents, where they got well established and naturalized. The pests associated with plants and seeds also moved along unnoticed into a new region, where they caused severe damage, not only to the plants with which they associated but started to infect / infests many other plant types in the introduced region. The realization of the economic, social consequences happened due to indiscriminate and unscientific movement or trade of plants, seeds and plant materials, necessitated the countries or provinces to start regulating the movement of plants and plant material.

In olden days the term "***Quarantine***" was originally applied to the period of detention of passengers arriving in ships from countries where epidemic diseases such as bubonic plague, cholera and yellow fever were prevalent. The ship's crew and passengers being compelled to remain isolated on board long enough to permit latent cases of diseases to develop and be detected before any persons were allowed to land. The word "**QUARANTINE**" is derived from the latin words ***"quarantum"*** or "***quaranta giorni***" meaning forty; that is to say a forty day period. In other languages – Italian: ***'quarantina'***; French: ***'quarante'***; Spanish: ***'cuarentena'*** all mean the same. Fixing of the period as forty has no scientific relevance at that time, but merely as practical measure based on necessity. Since the term Quarantine is so aptly fitted to and so firmly associated with an entirely unique situation, it was carried over from the human disease field into similar animal disease field and later adopted to cover protective efforts for the exclusion of pests and diseases of farm and horticultural crops, as well as forest and fruit trees. Thus arose the Plant Quarantine.

WHAT IS PLANT QUARANTINE?

The plant quarantine system is the first line of defense against the introduction and possible establishment of exotic plant pests. Plant Quarantine laws, regulations and services are based on national and international agreements, which evolved during nineteenth and twentieth centuries around the world. These were formulated on agricultural and economic needs. There is a historical background for the creation of PQ system.

WHY PLANT QUARANTINE?

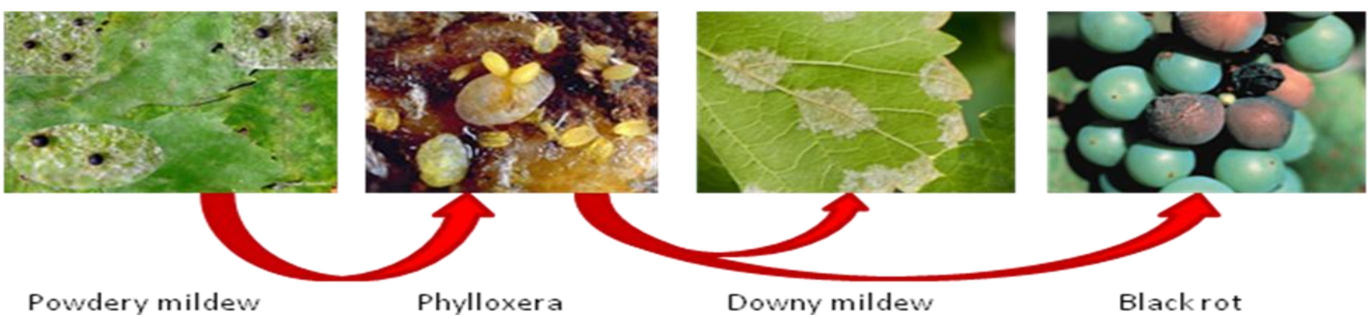
Since the dawn of civilization, man utilized his best possible efforts to domesticate the bounty of nature as per his needs. It is not just in recent years that the countries are being invaded by alien species, since time immemorial, man started to move the plants and animals wherever he fancied. In 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. To promote safe trade of agricultural materials across transboundary movement around the world implementation of plant quarantine system has become a necessity to safeguard biodiversity of a nation. Plant quarantine acts as a filter and not as a barrier of trade.

HISTORICAL BACKGROUND:

Few devastating incidences which had taken place in the late 17th and early 18th century lead to the creation of plant quarantine at global level.

Great Famine of Irish: Potato was introduced into Ireland as a garden crop and during late 17th century it was consumed as supplementary food. By early 18th 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.

REGULATIONS

The Regulations, initially it started as prohibition of plants and plant parts from specific countries due to past experience of invasive species. The first effort towards international agreement on Plant Protection was made in 1914 under auspices of the International Institute of Agriculture in Rome. This was followed by an International Convention on Plant Protection by over 50 member countries of the Institute in 1919 and certain Agreement regarding the issue and acceptance of Phytosanitary Certificate were finalized. Appreciating the need for the Convention to strengthen such international efforts, FAO sponsored an International Plant Protection Convention in 1951. India became a member in 1956 and agreed to adopt legislative measures specified in the Convention for the purpose of securing common and effective action to prevent the introduction and spread of pests and diseases of plants and plant materials and to promote measures for their control. PQ regulations are entrusted with public authority to legally establish barriers against the dissemination of injurious pests. This has remained unchanged till today. The need for PQ being entrusted to public authority is considered as one of the fundamental principles of PQ. The following are few interesting years in PQ:

- ❖ The very first regulations were enacted by French Government in 1913 but came into effect only in 1923
- ❖ The German Government started to put ban on plants and plant products from USA in 1913
- ❖ In USA, the PQ work started well ahead in 1891 when the State of California initiated seaport inspection at San Pedro, probably the first in the world. The Federal Plant Quarantine Act was enacted in 1912.
- ❖ Indonesia enacted a law to prohibit importation of coffee plants and beans from Sri Lanka in 1877
- ❖ In Australia the first set of regulations governing PQ came into force on 1909 following introduction of the Quarantine Act of 1908
- ❖ In India the first regulation – the Destructive Insects and Pests Act, 1914 came into force

Now almost all the countries have PQ regulations in force.

The establishment of PQ regulations or orders is not simple or easy because the problems to be considered are of a complex nature involving not only biological factors, but those of economic, social and political as well. It is important that those involved in the establishment of PQ service and enforcement of PQ regulations possess an excellent knowledge of the various factors to be considered and strike a balance among them.

To achieve complete success against the invasive species it is needed to have complete liaison with Customs Service to implement PQ Regulations in Toto. If the Customs service overlooks a few dutiful items like liquor or electronic goods or even few bars of gold to enter illegally into our country, the result is loss of few thousands of rupees, whereas for a living invader such as an insect, mite, plant pathogen, nematode or weed, a high level of effectiveness is indispensable or else our country's agricultural programs may be jeopardized. India has varied agro-climatic zones, which has benefited the farming industry, an untoward introduction of exotic pest shall cripple the economy of the country.

Definition and Objective of PQ:

Plant Quarantine is defined as "All activities designed to prevent the introduction and/or spread of quarantine pests or to ensure their official control" *(*FAO).

Pest is defined as "Any species, strain or biotype of plant, animal or pathogenic agent injurious to plants or plant products" (FAO)

Quarantine Pest is defined as "A pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being Officially controlled". (FAO)

The Objectives of "Plant Quarantine" are two fold:

(1) To prevent the introduction and establishment of an exotic species of a plant pest or disease

(2) **To eradicate, control or retard the spread of any such pest or disease that already has been introduced.**

PQ IN INDIA

The DIP Act, 1914:

In Order to protect the agricultural and forest plants of our country, the Government of India has taken legislative steps as far back as 1914 and passed an Act called, "The Destructive Insects and Pests Act, 1914 (Act II of 1914) for regulation of import of plants and plant products. Prior to establishment of the Directorate of Plant Protection, Quarantine and Storage in May 1946, under the Ministry of Food and Agriculture, the various rules and regulations of the DIP Act were enforced by the Customs Department as if the rules were issued under the Sea Customs Act. The result was that many new pests and diseases entered into India due to unscientific method of inspection and clearance. The Great Bengal Famine which wiped out 3 million people of India in 1942-43 acted as precursor for the establishment of Plant Protection Directorate in 1946 and the GOI decided to establish Plant Quarantine Stations at various international airports, seaports and land frontier check posts for effective implementation of plant quarantine regulations.

The Great Bengal Famine:

The Great Bengal Famine of 1943 occurred in undivided Bengal (Bangladesh and West Bengal). It is estimated that over three million people died from starvation and malnutrition, and related illnesses during the famine. In the rice growing season of 1942- 1943, weather conditions were exactly right to encourage an epidemic of the rice disease brown spot. Brown spot in rice is caused by the fungus *Helminthosporium oryzae*; the outbreak of the disease caused almost complete destruction of the rice crop (97%). Severe food shortages were worsened by the Second World War, with the British administration of India exporting foods to Allied soldiers and the ban of rice imports from Burma following the Japanese control of the country.

IMPORT REGULATIONS:

- **1914 – Destructive Insects and Pests Act, 1914**
- **1936 - Import Regulations**
- **1972 – Regulations to import cotton**
- **1984 – PFS Order, 1984**
- **1988 – National Policy on Seed Development**
- **1989 – PFS Order, 1989 (revised)**
- **1992 – Amendment to DIP Act – for levying import inspection fee**
- **2003 – Plant Quarantine (Regulation of Import into India) Order, 2003**

The Great Bengal Famine played a major role in opening of Plant Quarantine Stations in important entry points to prevent the entry of exotic pests into India. The GOI realized the importance of Plant Quarantine as first step of defense to control the entry of invasive species of plants and plant materials.

PLANT QUARANTINE STATIONS IN INDIA:

Though the Directorate was formed in 1946 with plant quarantine wing, the first Plant Quarantine Station was established at Mumbai in 1949 followed by the PQS at Chennai in 1950, Amritsar in 1954, Cochin in 1955, Kolkata in 1956, Visakhapattinam in 1957 and at Tuticorin and Bhavnagar in 1968. Presently, there are 35 PQS's functioning at various Seaports, Airports and Land frontier stations, in addition to 61 In-land depots to carry out plant quarantine inspection and to facilitate safe import of plants/ plant materials. All member countries of IPPC need to establish National Plant Protection Organization (NPPO) for implementation of phytosanitary measures, import regulations to promote safe agricultural trade through plant quarantine system, DPPQS is the NPPO for India.

Plant Quarantine (Regulation of Import into India) Order, 2003 (PQ Order, 2003):
Notified under the DIP Act and came into force with effect from 1st January, 2004. The PQ Order, 2003 replaces all the preceding Orders / notifications of plant quarantine regulations. PQ Order, 2003 was formulated on the scientific basis of Pest Risk Analysis (PRA). The commodities are categorized into various Schedules based on associated pest risk either through pathway or from countries where the pest is known to be reported. In Toto, the order clearly spells out notified points of entry, list of prohibited, restricted, regulated commodities, quarantine weeds of concern to India, Inspection fee, authorities to issue import permits, to certify post entry quarantine facilities (PEQ) and the deposition of samples to gene bank of NBPGR.

PHYTOSANITARY TREATMENTS – AN OVERVIEW

There is a tremendous increase in international trade in the past two decades. The removal of quantity restrictions has enhanced bulk trade of agricultural materials across the globe. Bulk trade of agricultural material always pose great threat to the biosecurity of a nation, as exotic pests can easily enter into newer areas. Plant Quarantine acts as a filter but not as a barrier to trade. It is true that 'zero' tolerance can not be achieved in trade of agricultural materials and always an element of threat is hidden. It is the responsibility of the importing country to safeguard from incursion of exotic pests (Quarantine pests) to safeguard food security of that nation. Further, it the responsibility of the exporting country to take care that, there materials are not the vehicle or means for spreading pests into importing country. Thus it is important that both countries need to implement plant quarantine regulations and respect each others phytosanitary requirements and promote safe, smooth and predictable trade. "Phytosanitary measures" are the measures applied to plants and plant materials to promote trade of agricultural materials and at the same time prevent spread of exotic, harmful plant pests into newer areas. The appropriate phytosanitary measure depends biology and nature of pest. For example insect infestation on consumption materials such as pulses and cereals etc., can be managed by fumigation, whereas insect infestation on plants needs spraying with insecticide, as it can not be fumigated due to addition of chloropicrin in Methyl bromide as warning agent, which is phytotoxic to plants (cause death / deterioration).
There are many phytsanitary treatments in practice as of now. A gist of such phytosanitary treatments are covered in this lecture.

POST HARVEST QUARANTINE TREATMENTS:

HOT WATER IMMERSION TREATMENT (HWIT)

Hot water immersion is an efficient treatment for some fruits and vegetables infested with fruit flies, borers, sucking pests etc. HWIT is specifically an efficient phytsanitary treatment to disinfest mango fruit of fruit flies and is the most common quarantine heat treatment in use today due to the volume of fresh commodity being traded. Large commercial hot water treatment facilities are routinely used to treat mangoes with hot water immersion at a temperature of 115 to 116ºF (46.1 to 47ºC) for 65 to 110 minutes, depending on fruit weight and variety. DPPQS has brought out National Standard for Phytosanitary Measures (NSPM 15) for guidelines for certification of HWIT facilities.

VAPOR HEAT TREATMENT (VHT)

Vapor heat, the oldest of the three methods of quarantine heat treatment, consists of heating the host fruit by moving hot air saturated with water vapor over the fruit surface. Vapor heat treatment (VHT) is a high humidity air treatment. When the mango is at dew point temperature or lower temperature, the air will condense on the fruit surface and the condensate will conduct heat energy from the surface into the center of fruit flesh. Heat is transferred from the air to the commodity by condensation of the water vapor (heat of condensation) on the relatively cooler fruit surface. Fruit may be heated over time to a target temperature of 46 – 48^{o}C for a period of 30 mins. holding time that is required to kill the insect pests. Treatments usually take 3 to 4 hours from start to end of heating.

Dry HEAT TREATMENT:

Dry heat treatment of Niger seeds at 120^{o}C for 15 minutes for devitalization of contaminant noxious weeds or prohibited pathogens in accordance with the applicable provisions of USDA PPQ Treatment Manual is required to be carried out prior to export as phytosantary treatment.

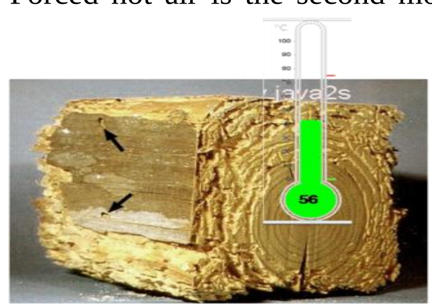
FORCED HOT-AIR HEATING TREATMENT (FHAT)

For treating perishable commodities:

Forced hot-air, also known as high-temperature forced air, is a modification of the vapor heat treatment developed by Armstrong et al. (1989) to kill Mediterranean fruit fly, melon fly and oriental fruit fly eggs and larvae in papaya. It is essentially the same as vapor heat except that the fruit surfaces are dry during forced hot-air treatment. Improvements in temperature and moisture monitoring and air delivery have advanced forced hot-air treatments, leading forced hot-air treatments to be developed for commodities previously treated with vapor heat and also being developed for new commodities. Forced hot-air treatment appears to be as effective in controlling internal pests as vapor heat, and provides better fruit quality, becoming the treatment of choice for many fruit previously treated with vapor heat. The fruit skin temperature remains cooler during forced hot air treatments than during vapor heat treatment while the tissue just below the skin heats to lethal temperatures because of the occurrence of evaporative cooling on the fruit surface during forced hot air treatment at lower relative humidity. Forced hot air is the second most common method of quarantine heat treatment.

For treating Timber logs and Wood packaging Materials:

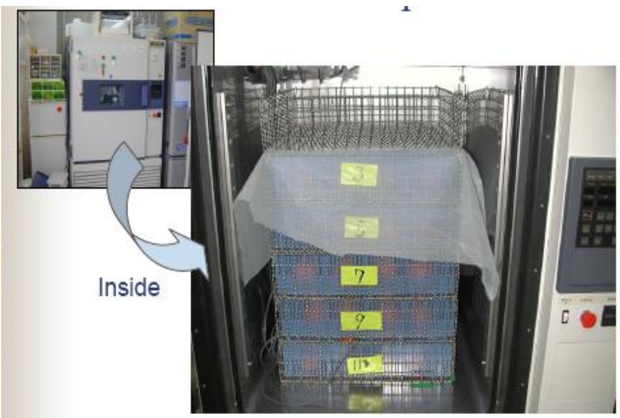
In order to protect the trees and forests, a number of countries have taken regulatory action to control the import of wood packaging materials. At present, **more than 50 countries** including **India** have taken such action. In an endeavour to bring some order to this situation and to control the spread of pests through wood packaging, the



Secretariat of **IPPC** (International Plant Protection Convention), identified approved measures that significantly reduce the risk of the spread of pests, by way of an international standard for harmonized treatment protocol, i.e. **ISPM-15:** "***Guidelines for regulating wood packaging material in the international trade***". This ISPM-15, was adopted in 2002 and is now implemented by many of the trading nations. As per the ISPM-15, the raw wood packaging material required to undergo approved treatment such as heat treatment (FHAT) at 56^0 C for 30 min and marked prior to export. In line with the ISPM 15, DPPQS has brought out NSPM-9 for accreditation of FHAT facilities in India to promote use of pest free packaging materials.

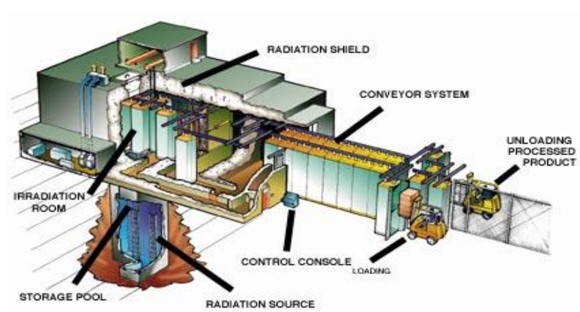
***COLD TREATMENT*:**

Cold treatment involves the refrigeration of produce over an extended period of time, according to treatment schedules established exporting / importing country requirements. Cold treatment is used to kill fruit flies in regulated articles as a prerequisite for movement of those articles out of fruit fly infested areas. Cold treatment is preferable to fumigation for commodities that are known to be damaged by methyl bromide. Cold treatment include exposing commodities to low temperatures (0^{o}C to 3^{o}C) for a certain period of days (i.e. 10 to 20 days), depending upon the life cycle of the fruit fly (i.e. egg to 3rd instar larval period). For example, cold storage of citrus fruits at temperatures of 2^{o}C or 3^{o}C can effectively kill Queensland Fruit Fly in citrus stored for 14 to 16 days.



IRRADIATION

Food irradiation is a process by which products are exposed to ionizing radiation to sterilize or kill insects and microbial pests by damaging their DNA. Radiation may be provided by gamma rays from cobalt-60 or cesium-137 sources, electrons generated from machine sources (e-beam), or by x-rays. Absorbed dose is measured as the quantity of radiation imparted per unit of mass of specified materials. The unit of absorbed dose is the gray (Gy) where 1 gray is equivalent to 1 joule per kilogram.



FUMIGATION:

Fumigation is the process of releasing and dispersing a toxic chemical so it reaches the target organism in a gaseous state. Chemicals applied as aerosols, smokes, mists, and fogs are suspensions of particulate matter in air and are not fumigants. The most effective way to reach pests in their most remote hiding places is through fumigation, the use of poisonous gases to kill pests in an enclosed area. To be effective, fumigants must reach target pests as gases. Fumigants are "wide-spectrum" pesticides, killing all species of arthropods

and rodents that are likely to be found in a building. They are also volatile pesticides whose vapors enter the insect's body through the body wall or breathing system. Fumigants penetrate to many areas of a building not reached by sprays or dusts, even penetrating to the burrows of wood-infesting insects, as well as to the center of tightly packed commodities, such as cotton bales, cases or grain in large silos or bulk bins. A fumigant gas generally does not leave unsightly, odorous, or hazardous residues. In India the only authorized fumigants are Methyl bromide (98% MBr plus 2% Chloropicrin) and Aluminium phosphide. Fumigation by Methyl bromide (100% MBr) is being used for some fresh commodities as phytosanitary measure in few countries against insect pests, including fruit flies. In India, Chloropicrin (2%) is added as a warning agent to MBr. Chloropicrin is phytotoxic and hence, MBr fumigation for fresh produce is not carried out in India. The approved fumigants in India are – Methyl bromide and Aluminium phosphide.

For treatment of perishable commodities:

Fumigation by Methyl bromide (100% MBr) is being used for some fresh commodities as phytosanitary measure in few countries against insect pests, including fruit flies. In India, Chloropicrin (2%) is added as a warning agent to MBr. Chloropicrin in phytotoxic and hence, MBr fumigation for fresh produce is not carried out in India.

For treatment of non-perishable commodities:

Commodities such as dry grains, pulses, cereals, timber logs, wood packaging materials, other plant materials can be fumigated with MBr or Aluminium Phosphide (AlP) to render pest free. Fumigation is the best option for bulk treatment of agricultural commodities. As per ISPM 15, MBr can be used for fumigating timber logs and wood packaging materials as a phytosanitary measure to prevent the spread of insect pests of concern to trees and forests. All stages of the wood boring insects are killed by MBr fumigation. NSPM-11 and 12 brought out by DPPQS directly deal with accreditation procedures for MBr facilities treatment of commodities either imported or exported.

DIPPING/ DRENCHING/ FOGGING/ DRESSING ETC USING PESTICIDES:

Wide variety of pesticides are used as phytosanitary treatment for export of planting materials. Dipping or Drenching or spraying of roots/ plants in pesticides to render pest free such as fungi, bacteria, insect, nematode are carried out prior to export either as precautionary measure or as per the requirement of the importing country. Seed dressing with fungicides are carried out as mitigation measure against fungal infections.

SYSTEMS APPROACH:

The appropriate level of protection for an importing country can be achieved by the application of combination of measures. System approaches integrate biological, physical and operational factors to meet quarantine requirements. A systems approach to mitigate risks could involve some of the following:

- certification of pest free areas, pest free places of production, or areas of low pest prevalence for certain quarantine pests, such as fruit flies;
- programs (e.g., cultural, mechanical, chemical) to control pests within orchards;
- packing-house procedures (e.g., washing, brushing, inspection of fruit) to eliminate external pests;
- quarantine treatments to disinfest fruit of internal and external pests;
- consignments inspected and certified by importing country phytosanitary officials and exporting country PQ officials to be free of quarantine pests;
- fruit traceable to state of origin, packing facility, grower, and orchard;

- consignments subject to sampling and inspection after arrival in the Importing country;
- limits on distribution and transit within the importing country.

ALIEN INVASIVE SPECIES – IMPACTS AND THREATS

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.

BENEFICIAL ALIEN SPECIES:

For example, coffee (from Yemen), Chilli (from Mexico), Rubber (by British), Soybean , Sunflower, etc. were brought to India and grown as beneficial crops. 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, Cardamom, Neem, Mango etc.

HARMFUL ALIEN SPECIES:

In the past scores of harmful alien species have entered into India and cause huge economic damage. They are categorized into two groups, namely alien species (exotic) and alien invasive species (exotic and invasive). To site a few:

ALIEN SPECIES (EXOTIC PESTS):

- Coffee pests such as Coffee rust, *Hemilia vastatrix*, coffee green scale (*Coccus viridis*), coffee berry borer (*Hypothenemus hampeii*) were intruded from Sri Lanka
- Coconut eriophid mite (*Aceria guerreronis*) probably from Sri Lanka

ALIEN INVASIVE SPECIES:

- Spiralling white fly (*Aleurodicus dispersus*) (Sri Lanka / Maldives).
- Papaya mealy bug (*Paracoccus marginatus)* (Thailand)
- Cotton mealy bug (*Phenococcus solenopsis*) (USA)
- *Phalaris minor* weed in wheat (USA)
- ***Parthenium hysterophorus*** is a major weed contaminated wheat imported from USA
- **Water hyacinth** (*Eichhornia crassipes*) is another such major weed clogging the waterways in India, brought as ornament from Mexico
- ***Lantana camara*** is another introduced, woody weed.
- **Mile-a-minute weed** (*Mikania micrantha*) is another invasive weed, which is smothering the forest and plantation vegetation in India.
- ***Salvinia molesta***, an aquatic weed native of Brazil

- ***Prosopis juliflora***, thorny, exotic weed introduced from Mexico and Caribbean Islands

RECENT TREND IN GLOBAL AGRICULTURAL TRADE:

Ever since the liberalization of trade has taken place in the post-WTO era, the term "Alien invasive species" has gained more emphasis among trading nations, as the impact of alien invasive species is the most dreaded in the context of climate change and the faster trade exchange between nations, which accelerates the crossing of boundaries of alien invasive species. The alien invasive species not only affect agriculture, horticulture, pasture lands and forests, they are also the cause for major impacts on environment and biodiversity of a nation. For example, weeds provide good proof to clarify what is meant by Invasive Species because most people understand what constitutes a 'weed'.

Definitions;

- **PEST** means *any species, strain or biotype of plant, animal or pathogenic agent injurious to plants and plant products* (PQ Order)
- **QUARANTINE PEST** means *a pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled* (PQ Order)
- **ALIEN SPECIES -** (non-native, non-indigenous, foreign, exotic) means *a species, subspecies, or lower taxon occurring outside of its natural range (past or present) and dispersal potential (i.e. outside the range it occupies naturally or could not occupy without direct or indirect introduction or care by humans) and includes any part, gametes or propagule of such species that might survive and subsequently reproduce.* (IUCN,2000)
- **ALIEN INVASIVE SPECIES -** means *an alien species which becomes established in natural or semi-natural ecosystems or habitat, is an agent of change, and threatens native biological diversity.* (IUCN,2000)
- **ECOSYSTEM** means the *complex of a community of organisms and its environment*.
- **WEED** is defined as "*A plant considered undesirable, unattractive, or troublesome, especially one growing where it is not wanted*". Or in simple words "*A plant that interferes with management objectives for a given area of land at a given point in time"*.

INTERNATIONAL EFFORTS TO PREVENT ENTRY OF INVASIVE ALIEN SPECIES:

Scientific evidence indicates that biological invasions are growing at an unprecedented rate, posing increasing threats to the diversity of life, and also disrupting ecosystem functionality. Global economies, as well as water supply, food security and human health are impacted negatively. Despite the urgency to take action against invasions, public awareness on the issue is inadequate

IPPC: The **International Plant Protection Convention** (**IPPC**) is an international treaty organization that aims to secure coordinated, effective action to prevent and to control the introduction and spread of pests of plants and plant products. The Convention extends beyond the protection of cultivated plants to the protection of natural flora and plant products. It takes into consideration both direct and indirect damage by pests (including weeds). IPPC is essentially a "Phytosanitary Agreement" – a mechanism for protecting agriculture from pests that could spread through international trade in plants and plant produce. Member countries are supposed to maintain inspection procedures for export and undertake eradication and control measures in the event of new pest infestations occur. Member countries require to establish NPPO (National Plant Protection Organization) to promote safe agricultural trade and to protect natural flora.

CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora): CITES is intended to protect endangered species from being collected for export. CITES protects many rare plants and animals from over exploitation and trading. Hence, it is considered as landmark advance in conservation of rare plants and animals and helps to preserve of biodiversity.

CBD (Convention on Biological Diversity): its objective is to develop national strategies for the conservation and sustainable use of biological diversity. The Convention has three main goals:

1. conservation of biological diversity (or biodiversity);
2. sustainable use of its components; and
3. fair and equitable sharing of benefits arising from genetic resources

CP (Cartagena Protocol on Biosafety) : The Biosafety Protocol seeks to protect biological diversity from the potential risks posed by **living modified organisms (LMO)** resulting from modern biotechnology.

IUCN: The **International Union for Conservation of Nature and Natural Resources** (**IUCN**) is an international organization dedicated to finding pragmatic solutions to the most pressing environment and development challenges. The organization publishes the IUCN Red List, compiling information from a network of conservation organizations to rate which species are most endangered.

ISSG (Invasive Species Specialist Group) is established under **IUCN** (International Union for Conservation of Nature). ISSG's network of leading specialists provide technical advice to policy makers, and, ISSG disseminates the most current and reliable information on invasive species ecology, their impacts on biological diversity and ways to prevent and control their spread. Further, a global analysis of extinction risk for the world's plants, conducted by the Royal Botanic Gardens, Kew together with the Natural History Museum, London and IUCN, has revealed that the world's plants are as threatened as mammals, with one in five of the world's plant species threatened with extinction.

UN-FCCC (United Nations – Framework convention on Climate Change): The Convention on Climate Change sets an overall framework for intergovernmental efforts to tackle the challenge posed by climate change. It recognizes that the climate system is a shared resource whose stability can be affected by industrial and other emissions of carbon dioxide and other greenhouse gases. The convention aims to stabilize and eventually reduce global Carbon emissions – an essential step in staving off a probable tidal wave of new invasions of pests that could be triggered by climate change.

Agenda 21 is an action plan of the United Nations (UN) related to sustainable development and was an outcome of the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro, Brazil, in 1992. It is a comprehensive blueprint of action to be taken globally, nationally and locally by organizations of the United Nations System, governments, and major groups in every area in which humans directly affect the environment.

NATIONAL EFFORTS TO PREVENT ENTRY OF INVASIVE ALIEN SPECIES:

Plant Quarantine System: The Plant Quarantine (Regulation of Import into India) Order, 2003 is aimed at preventing the entry, establishment and spread of alien invasive species into India through plant quarantine mechanism. Plant quarantine acts as the first line of defense at the entry points.

Germplasm Exchange: The incursion of dangerous pests coming through the germplasm material is monitored by NBPGR (National Bureau of Plant Genetic Resources)

Research Institutes: The crop research institutes of ICAR (Indian Council of Agricultural Research) are responsible for monitoring the planting materials imported for research to prevent entry of alien invasive species.

Biosecurity Authority: There is an urgent need to bring all the relevant fields/ organizations under one umbrella to safeguard biosecurity of the nation. For this a National Agricultural Biosecurity Authority (NABS) needs to be setup. Government of India has taken initiative towards establishing NABS and in near future the same shall come into force.

Surveillance: As of now surveillance is carried out by individual departments, governments, institutes, NGOs, individuals etc. without much network and information sharing. Surveillance mechanism needs to be integrated with Biosecurity Authority to know pest status and carry out eradication programmes in the event of pest incursion.

Pest Diagnosis: Precise identification of pest is a major concern in the event of exotic pest incursion or new pest reports. Human resource and centralized pest repository are the major thrust area, which needs strengthening.

NEED OF THE HOUR TO COMBAT INVASIVE ALIEN SPECIES IN INDIA:

The past bitter and costly experiences learnt due to the impact of introduced invasive species has lead to the awakening of plant battle field to combat the entry of invasive alien weeds and other species which might topple the economy, destroy the ecology, and disturb the environment of India. Stringent legal regulations, public awareness, coordinated efforts by the scientific and farming community with administrative backup, preparedness with eradication measures in case of entry, instant sharing of notice of invasive weeds through network among states and central to take appropriate action at appropriate time etc. are all the need of the hour to combat entry of invasive weeds.

Some of the frustrating questions on incursion of Alien invasive species:

- We do not know **which** organisms will become successful invasive species
- We do not know **where** the invasion will take place
- We do not know **when** the invasion will occur
- We do not know **what** an invasion will do