Topic No. 1& 2

-IPM: Introduction, history, importance, concepts.

- Principles and tools of IPM

- **Integrated pest management** (**IPM**), also known as **integrated pest control** (**IPC**) is a broad-based approach that integrates practices for economic control of pests. IPM aims to suppress pest populations below the economic injury level (EIL).
- **INTEGRATED PLANT DISEASE MANAGEMENT (IPDM)**

IPDM involve management systems which utilize compatible combinations of all theavailable techniques to keep the pathogen population below the economic threshold level (ETL) which would not result in economically unacceptable damage to the crop. IPDM isbased on five principles of plant disease management and integrates multidisciplinaryapproaches for the management of plant diseases.

The main goals of an integrated plant disease controlprogram are

(1) eliminate or reduce the initial inoculum,

(2) reduce the effectiveness of initial inoculum,

(3)increase the slow the secondary cycles.

- **History of IPM**
  - Shortly after World War II, when **synthetic insecticides** became widely available, entomologists in California developed the concept of "supervised insect control". Around the same time, entomologists in the US **Cotton Belt** were advocating a similar approach. Under this scheme, insect control was "supervised" by qualified entomologists and insecticide applications were based on conclusions reached from periodic monitoring of pest and natural-enemy populations. This was viewed as an alternative to calendar-based programs. Supervised control was based on knowledge of the ecology and analysis of projected trends in pest and natural-enemy populations.
  - Supervised control formed much of the conceptual basis for the "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. Chemical insecticides were to be used in the manner least disruptive to biological control. The term "integrated" was thus synonymous with "compatible." Chemical controls were to be applied only after regular monitoring indicated that a pest population had reached a level (the economic threshold) that required treatment to prevent the population from reaching a level (the economic injury level) at which economic losses would exceed the cost of the control measures.
  - IPM extended the concept of integrated control to all classes of pests and was expanded to include all tactics. Controls such as pesticides were to be applied as in integrated control, but these now had to be compatible with tactics for all classes of pests. Other tactics, such

as host-plant resistance and cultural manipulations, became part of the IPM framework. IPM combined **entomologists, plant pathologists, nematologists** and weed scientists.

- In the United States, IPM was formulated into national policy in February 1972 when President **Richard Nixon** directed federal agencies to take steps to advance the application of IPM in all relevant sectors.
- In 1979, President **Jimmy Carter** established an interagency IPM Coordinating Committee to ensure development and implementation of IPM practices.
- **Perry Adkisson** and **Ray F. Smith** received the 1997 **World Food Prize** for encouraging the use of IPM.

- **Main components/tools of IPDM**:

1. Cultural practices
2. Regulatory measures (quarantine)
3. Chemical methods
4. Biological methods
5. Physical methods
6. Genetic engineering

- **Main strategies/Principles of IPDM:**

1. Need based application of pesticides
2. Encouragement and enhancement of biocontrol agents
3. Use of resistant or tolerant cultivars of plants
4. Modification of cultural practices
5. Use of any other strategies that interrupts host-pathogen interactions

- **Advantages of IPDM**:

1. Avoids chemical pollution of soil, water, air and food products
2. Avoids development of resistance in the plant pathogens against fungicides
3. It is an eco-friendly strategy for management of plant diseases
4. It is an economically feasible approach
5. It is a multipronged strategy for efficient management of plant diseases

Therefore, IPDM utilizes all suitable strategies in a compatible manner to reduce andmaintain pathogen populations at levels below those causing economic losses.

- **Rice diseases and IPDM:**

Fungal diseases

1. Blast: Foliar disease and the pathogen survives on collateral hosts
2. Brown spot of rice – Seed borne and a foliar disease
3. Sheath rot, sheath blight, foot rot and stem rot – Soil borne diseases
4. False smut – seed borne disease

Bacterial diseases: Bacterial leaf blight and bacterial leaf streak – Seed borne andsurvives on collateral hosts and weeds

Viral or Phytoplasmal diseases – Rice tungro virus, Rice yellow dwarf – Survives onweeds and dissemination is by insect vectors

IPDM strategy in rice:

1. Selection of healthy seed
2. Selection of resistant cultivars
3. Removal and destruction of collateral hosts
4. Balanced fertilization
5. Rouging of diseased plants
6. Seed treatment with carbendazim or tricyclazole at 2g/Kg seed
7. Need based foliar application of carbendazim@0.1% or Tricyclazole@0.06%for the management of blast.
8. Need based foliar application of validamycin for the management of sheath blight and sheath rot.
9. Soil application of carbofuran granules or foliar spray of any systemic fungicide is followed to manage insect vectors, thereby decreasing the spread of viral diseases.

- **Sugarcane diseases and IPDM**

1. Red rot – sett borne disease which spreads through irrigation water
2. Whip smut - sett borne and disseminate through wind borne sporidia
3. Pine apple disease, sett rot – Sett borne disease
4. Grassy shoot – Vector borne Phytoplasmal disease
5. Ratoon stunting – Sett borne (*Clavibacterxyli*)
6. Sugarcane mosaic – Survives on weeds and disseminated by insect vectors

IPDM in sugarcane:

1. Collection and destruction of infected crop debris
2. Hot water treatment of setts (520C for 30 min)
3. Hot air treatment of setts (540C for 2-3 hrs)
4. Balanced irrigation and fertilization
5. Avoid selection of seed material from Ratoon crop
6. Need based spray of systemic insecticides to minimize the spread of viral and Phytoplasmal diseases
7. Selection of disease resistant or tolerant cultivars

Topic No.3
Economic importance of diseases

- **Definitions:**
  1. **Disease** is a malfunctioning process that is caused by continuous irritation whichresults in some suffering producing symptoms (American Phytopathological society& British Mycological society).
  2. **Disease** is an alteration in one or more of the ordered sequential series ofphysiological processes culminating in a loss of coordination of energy utilization in aplant as a result of continuous irritation from the presence or absence of some agentor factor.
  3. **Disease:** Any malfunctioning of host cells and tissues that result from continuousirritation by a pathogenic agent or environmental factor and leads to development ofsymptoms (G.N.Agrios, 1997).

Pathogens bring about these irritating processes through different but inter-relatedpathways

a) by utilizing the host cell contents,
b) by causing death of cells or by interfering with their metabolic activities throughtheir enzymes, toxins and growth regulators,
c) by weakening of tissues due to continuous loss of nutrients, and
d) by interfering with translocation of food, minerals and water.

- **Plant disease and its importance**
  - Plant disease, an impairment of the normal state of a plant that interrupts or modifies its vital functions.
  - Plant disease outbreaks with similar far-reaching effects in more recent times include

Late blight of potato in Ireland (1845–60)

Powdery and downy mildew of grape - France (1851 and 1882)

Coffee rust - Ceylon (starting in the 1870s);

Sigatoka leaf spot and panama disease of banana - Central America (1910–1913)

Black stem rust of wheat - (1916, 1935, 1953–54)

- Loss of crops from plant diseases may result in hunger and starvation, especially in less developed countries where access to disease-control methods is limited and annual losses of 30 to 50 percent are common for major crops.
- In some years, losses are much greater, producing catastrophic results for those who depend on the crop for food.
- Major disease outbreaks among food crops have led to famines and mass migrations throughout history.
- The devastating outbreak of late blight of potato (*Phytophthorainfestans*) that began in Europe in 1845 and brought about the Irish famine caused starvation, death, and mass migration of the Irish population.

- **Diseases—a normal part of nature:**
  - Plant diseases are a normal part of nature and one of many ecological factors that help keep the hundreds of thousands of living plants and animals in balance with one another
  - Plant cells contain special signaling pathways that enhance their defenses against insects, animals, and pathogens. One such example involves a plant hormone called **jasmonate (jasmonic acid).**
  - In the absence of harmful stimuli, jasmonate binds to special proteins, called JAZ proteins, to regulate plant growth, Pollen production, and other.It also increase the defense mechanism of plants.

Topic No.4

Pest risk analysis

- **Pest risk analysis** (PRA) is a form of risk analysis conducted by regulatory plant health authorities to identify the appropriate phytosanitary measures required to protect plant resources against new or emerging pests and regulated pests of plants or plant products.
- Specifically pest risk analysis is a term used within the International Plant Protection Convention (IPPC) and is defined within the glossary of phytosanitary terms.as "the process of evaluating biological or other scientific and economic evidence to determine whether an organism is a pest, whether it should be regulated, and the strength of any phytosanitary measures to be taken against it".
- In a phytosanitary context, the term plant pest, or simply pest, refers to any species, strain or biotype of plant, animal or pathogenic agent injurious to plants or plant products and includes plant pathogenic bacteria, fungi, fungus-like organisms, viruses and virus like organisms, as well as insects, mites, nematodes and weeds.

- **Types of Pest Risk Analysis**

Pest risk analysis is most commonly applied for different purposes (IPPC, 2004,2007), namely:

- Analysing risks for organisms;
- Analysing risks for pathways;
- Analysing risks for commodities;
- Supporting new policies or changes toexisting policies;
- Prioritizing resources.

- At the most basic level, a single pestmay be analyzed in a pest risk analysis, and this is often referred to as an ‘organismspecificpest risk analysis’.
- For imports andexports of agricultural products, pest riskanalyses are conducted for the commoditiesin question. In this case, the ‘commodity pestrisk analysis’ typically considers manyorganisms that may move with a particularcommodity in trade.
- Alternatively, a pestrisk analysis may be very broadly applied toconsider pathways. A ‘pathway pest riskanalysis’ typically considers different typesof pathways, or means by which a pest canspread from one place to another.
- A pathwaypest risk analysis can examine a single pathway,or multiple pathways, and may be concernedwith a single pest or multiple pests.

- A commodity is one type of pathway (and acommodity pest risk analysis is one type ofpathway pest risk analysis), however manyother pathways may be the subject of ananalysis, including natural spread.
- A pestrisk analysis may also be done to support therevision of existing policies or implementationof new policies. For instance, a countrymay conduct a pest risk analysis on the levelof trade in various ports to determine whethera change in port policies is needed.
- Furthermore, any of these different pestrisk analyses may incorporate a variety ofmethods and processes to analyse risk. Thedifferent methodsuse of mapping and geographic information systems, economic analysis, quantitativeanalysis and qualitative analysis. The methodsthat are used for the analysis dependlargely on the type and scope of the problembeing analysed, the data available toconduct the analysis and the overall needfor the analysis in terms of detail, time andaudience.
- The different types of pest risk analysesvary in complexity, depending on the natureof the problem, the audience or applicationof the pest risk analysis and the availabilityof scientific and other information to supportthe analysis.

Topic No.5.

Methods of detection and diagnosis of diseases

Detection & Diagnosis

Detection :

- Process of identifying the presence of something *i.e* observation/ noticing/ recognition

Diagnosis :

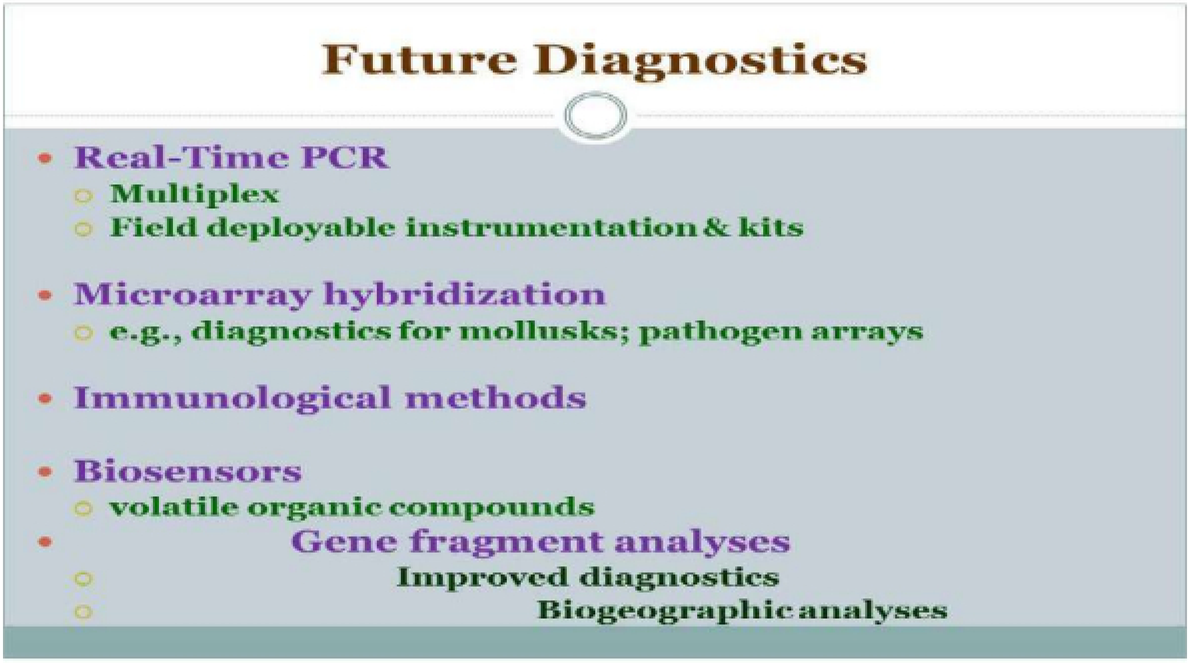
Identification of nature of illness/problem by examination of symptoms

Tools:

- **Plant sciences, especially Plant Pathology .**
- **Arts of investigation and detective work**

Diagnostic Techniques

- **Conventional :**
- Observation of Symptoms (frequently not definitive)
- Morphology of pathogens
- Culture
- Knowledge base (something new & different)
- Biochemical analyses
- **Modern :**
- Immunology (ELISA)
- Molecular diagnostics (PCR)



1. Observation of symptoms and sign

1. Thousands of plant diseases have been recorded throughout the world, many of these causing heavy crop losses. Early detection and accurate diagnosis is essential for the effective management of plant disease.

Thus the first step in studying any disease is its timely detection of the diseased plant. Quick initial detection is largely based on the signs and symptoms of disease.

- **Signs** are the visible physical presence of either the pathogen itself or the structures formed by the pathogen. Common examples of easily detected signs are those such as the fungal mycelia and spore masses of downy mildews observed on infected leaves and the bacterial ooze of *Xanthomonas* leaf streak disease on rice.[2]

- **Symptoms** are the visible changes that occur in the host plant in response to infection by pathogens. For any disease in a given plant, there is the characteristic expression of symptoms, usually occurring in a sequential series during the course of the disease. This series of symptoms depicting the disease picture is referred to as the **disease syndrome**.

Morphological symptoms may be exhibited by the entire plant or by any organ of the plant. These have been categorized into different groups for easy of study. Primarily, morphological symptoms of plant diseases can be categorized into 6 different types.[4]

- Necroses
- Growth abnormalities
- Metaplastic symptoms
- Proleptic symptoms
- Color changes
- Wilts

Laboratory Examination and Testing

- Dissecting microscope
- Compound microscope
- Electron microscope

- Moist chamber incubation
- Culturing

- Additional tests for biotic agents

- Tests for abiotic agents

Laboratory Examination by using dissecting microscope

- Observe sporulation that's invisible to naked eye.
- Closer view of structures seen by naked eye
- Nematologist can ID nematodes to genus.

Laboratory Examination using microscope of higher magnification

Rust spores, *Puccinia* sp.

- ID fungi to genus or to species.
- View bacterial flow; observe morphology at highest magnification.
- View virus inclusion bodies.
- Using electron microscope, view viruses, phytoplasmas

Laboratory tests

Moist chamber

Moist Incubation

- Goal – to induce sporulation
- Important for obligate fungal pathogens
- Avoid overly moist conditions.
- Can surface sterilize

Laboratory tests

Fungal culture.

Fungal isolation

- Surface sterilize.
- Use margin of diseased area.
- Nutritive agar media, can be selective
- Diagnostician can often ID to genus from appearance of culture

Koch

- Robert Koch – German physician in late 1800s
- Proved that a bacterium caused anthrax in cattle
- Developed steps proving the bacterium was causal
- Same steps used to prove pathogenicity for plant disease organisms

Koch's Postulates

1. Note constant association of organism with diseased plants and consistent, observable symptoms.

2. Isolate and characterize organism in pure culture.

3. Inoculate healthy plant with organism, and observe the same disease and symptoms.
4. Re-isolate same organism.

Final Diagnosis
(Plant Disease Diagnosis Steps)

All information compiled and analyzed

Organism identified, found to be pathogen of host

OR

Lab tests, other information reveal an abiotic cause

Develop control recommendations and present to grower.

Topic No.6

Measurement of losses causes due to diseases

- **ASSESSMENT OF CROP LOSSES**

Some basic concepts

The measurable produce from a crop is referred as the '**Yield'. 'Crop loss'**is a reduction in either quantity and/or quality of yield. When crops are grown under optimal conditions using fully the available modern technology, such as, for example, in experimental plots, the resulting high yields and high quality are referred to as **'attainable'**yield. When crops are grown under farm condition yields are obtained which are often less than the attainable ones. These are referred to as the **'actual'**yields. Research and extension workers in all agricultural regions are concerned to improve crop production by raising 'actual' yields to attainable levels. Crop protection is of basic importance in this situation.

Many different types of measurement are used for recording disease (i.e. incidence and intensity of harmful organisms). The extent of infection or of plant damage is instead frequently adapted to measure disease intensity. Feeding and other activities by harmful organisms may have little effect on growth or visual appearance of the crop with no consequent effects on yield. This is referred to as **'apparent crop injury'**while**'crop damage'**is instead used to describe injuries by harmful organisms, which collectively result in a measurable loss of yield.

It is sometimes possible to establish under a well-defined set of conditions intensity levels of disease at which crop damage has not yet occurred but is likely to take place if no control measures are taken. These levels (often referred to in the literature as 'critical levels') are important as they serve to guide growers and plant protection specialists in taking immediate control measures. Similar levels can occasionally be established for certain soil borne diseases or nematodes before susceptible crops are planted.

One of the most important aspects in establishing intensity/loss relationships is the correct timing of assessment in relation to crop development. Many crop plants are, for instance, able to compensate for injuries incurred early in their growth.

The assessment of yield can be done by two ways

1) **Field experimentation and**
2) **Sample surveys**

1. FIELD EXPERIMENTS FOR ASSESSMENT OF CROP LOSSES

Important considerations for conducting crop loss assessment experiments:

1) Estimates of crop losses caused by harmful organisms can be worked out for a particular region or country.
2) The experiments should be simple, standardized and be conducted on farms and experiment stations.
3) Experiments should be conducted for at least three years at each of a number of locations.
4) The crop loss assessment information needs to be updated, perhaps every five years.

5) Due to tremendous variation in cultivation and other practices in agriculture, absolute values for losses cannot be obtained in practice.
6) Neither disease population nor crop losses are static, nor do they change from year to year in a given location.
7) However, useful results can be obtained from properly designed and well-conducted field experiment.
8) In most cases, estimates within a 10 to 15% margin of error are acceptable for all practical purposes.

Experimental methods for the assessment of crop losses always involve:

1) Uniform and reproducible appraisal of disease intensity;
2) Determination of crop yields and or the relationship between disease and yield and
3) Use of statistical techniques to summarize and evaluate the validity of the experimental results.

Numerica1 categories or scores of intensities established experimentally and tested for adequately and practicability should be used to characterize specific situations. In practice, disease intensity in or on a given plant/crop area is measured by one of the following methods depending upon the kind of disease and or the crop involved:

a) Actual counts (number of spots, total area covered) or determination of weight or volume of specimens collected.
b) Visual rating of disease with defined scored cards.
c) Actual counts of plant or crop units damaged or affected by the disease.
d) Visual ratings of damaged plants or plant parts in classes defined by descriptive scales or diagrams.

Care to be taken while planning the crop loss assessment experiments:

a) Quite often fungicides are used to regulate or establish disease-intensity levels. When this is done, it should be emphasized that some of these chemicals, and/or their solvents and carriers, may increase or decrease crop yield responses independently from their effects on the disease. Therefore, where accurate estimates are desired, it is important to confirm that the chemicals are not introducing bias in the results.
b) When disease intensity values are to be used in conjunction with yield data to estimate crop losses, a clear indication must be given of the time when such values are determined in relation to plant or crop development.
c) Care should be taken that all plots are accurately and permanently marked and that all cultural operations are uniform for all plots.
d) Commonly, loss estimates have been based on reduction of yield. Assessment of losses should also include the reduction in market value of the crop due to the lowering of its quality by diseases. Variation in market standards from area to area may prevent a uniform approach to the quality problem.

Planning and conducting crop loss experiments

The kind of assessment experiment required in a particular situation will depend upon

1) The type of disease/crop relationship under study and
2) The ultimate use to be made of the data.

The primary objective of most crop loss experiments is a comparison of controlled and non-controlled conditions (paired-treatment experiments) that involve an estimate of disease intensity and yield on a number of experimental sites. Occasionally the comparison is between a large number of diseased and healthy plants by the paired plant method. More sophisticated experiments are occasionally conducted to determine

a) The relationship of various intensity levels of a disease to reduction in yield and
b) The joint effects on yield of combinations of more than one disease.

In addition to yield data from each plot, the following records should be obtained:

a) Crop variety;
b) Type of planting (distance between rows; number of plants/hill, etc.);
c) Dimension of plots harvested and number of harvests/units (rows, trees, etc.);
d) Number of replications;
e) Disease species present and time of its initial infection (possibly related to stage of plant development);
f) Presence and intensity of other disease(s);
g) Lodging of crop, difficulty in harvesting increased labour requirements for the removal of disease-infested plant or crop parts, etc.

2.USE OF SAMPLE SURVEY IN CROP LOSS ESTIMATION

REQUIREMENTS FOR SUCCESSFUL AGRICULTURAL SURVEYS

1) To define objectives adequately.
2) Usefully consider whether survey methods are appropriate
3) What techniques are to be practicable and efficient?
4) Broadly, decisions are always needed on:
   i. The region (or 'population') to be covered by the survey,
   ii. The characteristics to be estimated,
   iii. The sub-regions or sub-classes (varieties, soil types, etc.) for which estimates are needed,
   iv. The accuracy required.
5) These decisions determine the main features of the survey plan:
   a. Influences the techniques and type of people required and
   b. The scale of the survey.

6) Survey planning is likely to be most effective when a draft of the required tables and a general outline of the -report is prepared at an early stage, because this helps to clarify objectives.
7) A survey should provide information from truly representative samples of the region under study.
8) The sample must be sufficient to provide estimates of required accuracy.

METHODS OF OBSERVATION AND MEASUREMENT

1) Methods should be consistent and reproducible as used by the field staff.
2) Should be as objective as possible.
3) Be acceptable to the farming community.

Record forms

All forms should be readily understood, and convenient for use in the field and for office processing. Only information known to the respondents, and which they are prepared to give, should be sought. Good questionnaires are brief.

Staff selection, training and supervision

The quality of staff must be appropriate to the work. All surveyors should know exactly what is expected of them and why. A training period will usually be essential. Good supervision is also needed to ensure that difficulties are resolved and a good standard of work maintained.

Establishing contact-public relations

Success depends on the collaboration of farmers and local officials; every effort must therefore be made to secure their trust and interest. This can sometimes be helped by advance publicity or by a letter of introduction; much also depends on the method of approach and personality of the surveyor.

Data processing and reporting

Before a survey beguns, a plan should be made for processing the data and ensuring the necessary clerical and computing facilities. Coding and computing should be carefully checked, because errors at this stage can invalidate much useful work. Consideration should be given to reporting of the results back to local officials and participating farmers by regional reports or discussion meetings.

Pilot survey and pre-test

A pilot survey, under similar conditions to those of the main survey, is essential, to check all aspects of the plan and obtain realistic estimates of the time and resources needed. The pilot survey should be done soon enough for necessary modifications and for retraining. For small surveys (50 or so farms) a formal pilot survey is impracticable, but methods should be pre-tested on a few farms during training.

Crop-loss estimation surveys

Three types of sample survey make a useful contribution to work on crop-loss:

(a) General appraisal of the crop-loss situation.

(b) Surveys of farm practice.

(c) Reliable estimation of losses caused by a particular disease.

Topic No.7

Methods of control: Host plant resistance, cultural, mechanical, physical,

- **HOST PLANT RESISTANCE (IMMUNIZATION)**

Disease resistance: It is the ability of a plant to overcome completely or in some degreethe effect of a pathogen or damaging factor.

Susceptibility: The inability of a plant to resist the effect of a pathogen or otherdamaging factor.

Advantages of resistant varieties:

1. Resistant varieties can be the most simple, practical, effective and economical methodof plant disease management.
2. They not only ensure protection against plant diseases but also save the time, energyand money spent on other measures of control
3. Resistant varieties, if evolved can be the only practical method of control of diseasessuch as wilts, viral diseases, rusts, etc.
4. They are non-toxic to human beings, animals and wild life and do not pollute theenvironment
5. They are effective only against the target organisms, whereas, chemical methods are not only effective against target organisms but also effective against non-targetorganisms.
6. The resistance gene, once introduced, is inherited and therefore permanent at no extracost.

Disadvantages:

1. Breeding of resistant varieties is a slow and expensive process
2. Resistance of the cultivar may be broken down with the evolution of the pathogen

Types of resistance:

1. **Vertical resistance**: When a variety is more resistant to some races of the pathogenthan others, the resistance is called vertical resistance (race-specific resistance, qualitativeresistance, discriminatory resistance). Vertical resistance is usually governed by singlegene and is unstable.
2. **Horizontal resistance**: When the resistance is uniformly spread against all the races of a pathogen, then it is called horizontal/generalized/non-specific/field/qualitativeresistance. Horizontal resistance is usually governed by several genes and is more stable.
3. **Monogenic resistance**: When the defense mechanism is controlled by a **single genepair**, it is called monogenic resistance.
4. **Oligogenic resistance**: when the defense mechanism is governed by a **few gene pairs**,it is called oligogenic resistance.

5. **Polygenic resistance**: When the defense mechanism is controlled by **many genes** ormore groups of supplementary genes, it is called polygenic resistance.

Cross protection: The phenomenon in which plant tissues infected with mild strain of avirus are protected from infection by other severe strains of the same virus. This strategyis used in the management of severe strains of *Citrus Tristeza**virus***

•Cultural methods –

a) Rouging: Removal of diseased plants or their affected organs from field, whichprevent the dissemination of plant pathogens.Ex: Loose smut of wheat and barley, whip smut of sugarcane, red rot of sugarcane, ergotof bajra, yellow vein mosaic of bhendi, khatte disease of cardamom, etc. During 1927-1935, to eradicate citus canker bacterium in USA, 3 million trees were cut down andburnt.

b) Eradication of alternate and collateral hosts: Eradication of alternate hosts will helpin management of many plant diseases.Ex: Barbery eradication programme in France and USA reduced the severity of blackstem rust of wheatEx: Eradication of *Thalictrum*species in USA to manage leaf rust of wheat caused by*Pucciniarecondita.*Eradication of collateral hosts, such as *Panicumrepens*, *Digitariamarginata*will help inthe management of rice blast disease (*Pyriculariaoryzae*)

c) Crop rotation: Continuous cultivation of the same crop in the same field helps in theperpetuation of the pathogen in the soil. Soils which are saturated by the pathogen areoften referred as **sick soils**. To reduce the incidence and severity of many soil bornediseases, crop rotation is adopted. Crop rotation is applicable to only root inhabitants andfacultative saprophytes, and may not work with soil inhabitants.Ex: Panama wilt of banana (long crop rotation), wheat soil borne mosaic (6 yrs) and clubroot of cabbage (6-10 yrs), etc.

d) Crop sanitation: Collection and destruction of plant debris from soil will help in themanagement of soil borne facultative saprophytes as most of these survive in plant debris.Collection and destruction of plant debris is an important method to reduce the primaryinoculum.

e) Manures and fertilizers: The deficiency or excess of a nutrient may predispose a plantto some diseases. Excessive nitrogen application aggravates diseases like stem rot,bacterial leaf blight and blast of rice. Nitrate form of nitrogen increases many diseases,whereas, phosphorous and potash application increases the resistance of the host.Addition of farm yard manure or organic manures such as green manure, 60-100 t/ha,helps to manage the diseases like cotton wilt, Ganoderma root rot of citrus, coconut, etc.

f) Mixed cropping: Root rot of cotton (*Phymatotrichumomnivorum*) is reduced whencotton is grown along with sorghum. Intercropping sorghum in cluster bean reduces theincidence of root rot and wilt (*Rhizoctoniasolani*)

g) Summer ploughing: Ploughing the soil during summer months expose soil to hotweather which will eradicate heat sensitive soil borne pathogens.

h) Soil amendments: Application of organic amendments like saw dust, straw, oil cake,etc., will effectively manage the diseases caused by *Pythium, Phytophthora, Verticillium,Macrophomina, Phymatotrichum*and *Aphanomyces*. Beneficial micro-organismsincreases in soil and helps in suppression of pathogenic microbes.Ex: Application of lime (2500 Kg/ha) reduces the club root of cabbage by increasing soilpH to 8.5Ex:

Application of Sulphur (900 Kg/ha) to soil brings the soil pH to 5.2 and reduces theincidence of common scab of potato (*Streptomyces scabies*).

i***j) Changing time of sowing***: Pathogens are able to infect susceptible plants under certainenvironmental conditions. Alternation in date of sowing can help avoidance of favourableconditions for the pathogens.Ex: Rice blast can be managed by changing planting season from June toSeptember/October.

j) Seed rate and plant density: Close spacing raises atmospheric humidity and favourssporulation by many pathogenic fungi. A spacing of 8'X8' instead of 7'X7' reducessigatoka disease of banana due to better ventilation and reduced humidity. High densityplanting in chillies leads to high incidence of damping off in nurseries.

k) Irrigation and drainage: The amount, frequency and method of irrigation may affectthe dissemination of certain plant pathogens. Many pathogens, including, *Pseudomonassolanacearum, X. campestrispv. oryzae*and *Colletotrichumfalcatum*are readilydisseminated through irrigation water. High soil moisture favours root knot and othernematodes and the root rots caused by species of *Sclerotium, Rhizoctonia, Pythium,Phytophthora, Phymatotrichum*, etc

- **PHYSICAL METHODS**: Physical methods include soil solarization and hot watertreatments.

i. Soil solarization: Soil solarization or slow soil pasteurization is the hydro/thermal soilheating accomplished by covering moist soil with polyethylene sheets as soil mulchduring summer months for 4-6 weeks. Soil solarization was developed for the first time inIsrael (Egley and Katan) for the management of plant pathogenic pests, diseases andweeds.

ii. Soil sterilization: Soil can be sterilized in green houses and sometimes in seed beds byaerated steam or hot water. At about 500C, nematodes, some oomycetous fungi and other water molds are killed. At about 60 and 720C, most of the plant pathogenic fungi andbacteria are killed. At about 820C, most weeds, plant pathogenic bacteria and insects arekilled. Heat tolerant weed seeds and some plant viruses, such as TMV are killed at ornear the boiling point (95-1000C).

iii. Hot water or Hot air treatment: Hot water treatment or hat air treatment willprevent the seed borne and sett borne infectious diseases. Hot water treatment of certainseeds, bulbs and nursery stock is done to kill many pathogens present in or on the seedand other propagating materials. Hot water treatment is used for controlling sett bornediseases of sugarcane [whip smut, grassy shoot and red rot of sugarcane (520C for 30min)] and loose smut of wheat (520C for 10 min).

Topic No.8

Legislative, biological and chemical control

• Legislative control –

Plant quarantine regulation: Plant quarantine is defined as " a legal restriction on the movement of agricultural commodities for the purpose of exclusion, prevention ordelaying the spread of the plant pests and diseases in uninfected areas".Plant quarantine laws were first enacted in **France** (1660), followed by Denmark (1903)and USA (1912). These rules were aimed at the rapid destruction or eradication ofbarbery bush which is an alternate host of *Pucciniagraministritici*.In India, plant quarantine rules and regulations were issued under **Destructive Insectsand Pests Act (DIPA)** in 1914. In India, 16 plant quarantine stations are in operation bythe "Directorate of plant protection and quarantine" under the ministry of food andagriculture, government of India.Plant quarantine measures are of 3 types.

1. Domestic quarantine: Rules and regulations issued prohibiting the movement ofinsects and diseases and their hosts from one state to another state in India is calleddomestic quarantine. Domestic quarantine in India exists for two pests (Rooted scale andSanjose scale) and three diseases (Bunchy top of banana, banana mosaic and wart ofpotato).

Bunchy top of banana: It is present in Kerala, Assam, Bihar, West Begal and Orissa.Transport of any part of *Musa* species excluding the fruit is prohibited from these statesto other states in India.

Banana mosaic: It is present in Maharashtra and Gujarat. Transport of any part of *Musa*species excluding the fruit is prohibited from these states to other states in India.

Wart of potato: It is endemic in Darjeeling area of West Bengal, therefore seed tubers arenot to be imported from West Bengal to other states.

2. Foreign quarantine: Rules and regulations issued prohibiting the import of plants,plant materials, insects and fungi into India from foreign countries by air, sea and land.Foreign quarantine rules may be general or specific. General rules aim at prevention ofintroduction of pests and diseases into a country, where as the specific rules aim atspecific diseases and insect pests. The plant materials are to be imported only through theprescribed ports of entry.

1. **Airports**: Bombay (Santacruz), Calcutta (Dum Dum), Madras (Meenambakam), Newdelhi (Palam, Safdarjung) and Tiruchurapally.
2. **Sea ports**: Bombay, Calcutta, Vishakapatnam, Trivandrum, Madras, Tuticorin, Cochinand Dhanushkoti.
3. **Land frontiers**: Hussainiwala (Ferozpur district of Punjab), Kharla (Amritsar districtof Punjab) and Sukhiapokri (Darjeeling district of West Bengal)

3. Total embargoes: Total restriction on import and export of agricultural commodities.

Phytosanitary certificate: It is an official certificate from the country of origin, whichshould accompany the consignment without which the material may be refused fromentry.

• Biological control –

Def: Biological control is the reduction of inoculum density or disease producing activityof a pathogen or a parasite in its active or dormant state by one or more organismsaccomplished naturally or through manipulation of the environment of host or antagonistby mass introduction of one or more antagonists (Baker and Cook, 1974)

Mechanisms of biological control

1. Competition: Most of the biocontrol agents are fast growing and they compete withplant pathogens for space, organic nutrients and minerals. Most aerobic and facultativeanaerobic micro-organisms respond to low iron stress by producing extracellular, lowmolecular weight (500-1000 daltons) iron transport agents, designated as **Siderophores**,which selectively make complex with iron (Fe^{3+}) with very high affinity. Siderophoreproducing strains are able to utilize Fe^{3+} - Siderophore complex and restrict the growth ofdeleterious micro-organisms mostly at the plant roots. Iron starvation prevents thegermination of spores of fungal pathogens in rhizosphere as well as rhizoplane.Siderophores produced by*Pseudomonas fluorescens* (known as **pseudobactins**or **pyoveridins**) helps in the controlof soft rot bacterium, *Erwiniacaratovora.*

2. Antibiosis: Antagonism mediated by specific or non-specific metabolites of microbialorigin, by lytic agents, enzymes, volatile compounds or other toxic substances is knownas antibiosis.

a. **Antibiotics**: Antibiotics are generally considered to be organic compounds of low molecular weight produced by microbes. At low concentrations, antibiotics aredeleterious to the growth or metabolic activities of other micro-organisms.Ex: *Gliocladiumvirens*produces **gliotoxin**that was responsible for the death of*Rhizoctoniasolani*on potato tubers.Ex: Colonization of pea seeds by *Trichoderma viride* resulted in the accumulation ofsignificant amount of the antibiotic **viridin**in the seeds, thus controlling *Pythiumultimum*.Ex: Some strains of *Pseudomonas fluorescens* produce a range of compounds, viz., 2,4-diacetylphloroglucinol (DAPG), phenazines, pyocyanin, which have broad spectrumactivity against many plant pathogenic bacteria and fungi

b. **Bacteriocins**: These are antibiotic like compounds with bactericidal specificity closelyrelated to the bacteriocin producer. Ex: The control of crown gall (caused by*Agrobacterium tumefaciens*) by the related *Agrobacterium radiobacter*strain K 84 is bythe production of bacteriocin, **Agrocin K84**.

c. **Volatile compounds**: Antibiosis mediated by volatile compounds has been observed inthe management of soil borne pathogens, viz., *Pythiumultimum, Rhizoctoniasolani*and*Verticillium dahlia*, by *Enterobacter cloacae*. The volatile fraction responsible forinhibition was identified as ammonia.

3. Hyperparasitism: Direct parasitism or lysis and death of the pathogen by anothermicro-organism when the pathogen is in parasitic phase is known as hyperparasitism.Ex: *T. harzianum* parasitize and lyse the mycelia of *Rhizoctonia*and *Sclerotium*.

Biocontrol agents for the management of plant pathogens

Biocontrol agent Pathogen/disease

1. *Ampelomycesquisqualis*Powdery mildew fungi
2. *Darlucafilum, Verticilliumlecanii*Rust fungi

Biocontrol agent Nematode

1. *Pasteuriapenetrans*(Bacteria) Juvenile parasite of root knot nematode
2. *Paecilomyceslilacinus*(Fungus) Egg parasite of *Meloidogyne incognita*

Important fungal biocontrol agents:

Most of the species of Trichoderma, viz., *T. harzianum, T. viride, T. virens*(*Gliocladiumvirens*) are used as biocontrol agents against soil borne diseases, such as, root rots,seedling rots, collar rots, damping off and wilts caused by the species of Pythium,Fusarium, Rhizoctonia, Macrophomina, Sclerotium, Verticillium, etc.Formulations of biocontrol agents available: *T. viride* (**Ecofit**, **Bioderma**in India), *G.virens*(**GlioGard**in USA), *T. harzianum* (**F-Stop** in USA) and *T. polysporum*(**BINABT**)

Important bacterial biocontrol agents:

1. *Pseudomonas fluorescens* (**Dagger-G** against damping off of cotton seedlings in USA)
2. *Bacillus subtilis*(**Kodiak** against damping off and soft rot in USA)

3. Agrobacterium radiobacter K-84 (**Gallex**or **Galltrol**against crown gall of stone fruitscaused by *Agrobacterium tumefaciens*)

Plant growth promoting Rhizobacteria (PGPR):

Rhizosphere bacteria that favourably affect plant growth and yield of commerciallyimportant crops are designated as plant growth promoting rhizobacteria. The growthpromoting ability of PGPR is due to their ability to produce phytohormones,Siderophores, Hydrogen cyanide (HCN), chitinases, volatile compounds or antibioticswhich will reduce infection of host through phyto-pathogenic micro-organisms.Many bacterial species, viz., *Bacillus subtilis, Pseudomonas fluorescens*, etc., are usuallyused for the management of plant pathogenic microbes. *Bacillus* has ecologicaladvantages as it produces endospores that are tolerant to extreme environmentalconditions. *Pseudomonas fluorescens* have been extensively used to manage soil borneplant pathogenic fungi due to their ability to use many carbon sources that exude from theroots and to compete with microflora by the production of antibiotics, HCN andSiderophores that suppress plant root pathogens