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# Integrated Disease Management

Integrated disease management (IDM) came under focus in 1960's when chemicals especially, fungicides and insecticides came under the attack from environmentalists due to the over use of chemicals that created the problems of environmental pollution, chemical residues in food stuff, land, water and air, and the associated health hazards.

- It focused on the other methods of disease control.
- It involved cultural, biological, epidemiological and alternative means to achieve the disease control.
- Nowadays, there is an emphasis on disease "management" rather than on "Control".

## Definition of IDM

"Disease management system that in the context of associated environment and population dynamics of microorganisms, utilizes all suitable techniques and methods in a manner as compatible as possible and maintains the disease below economic level".

- In general, it is the integration of all possible and suitable management techniques for the control of diseases.
- The practices which need to be avoided in IDM are indiscriminate use of fungicides, monoculture and growing of susceptible cultivars.
- Integrated disease management ensures the proper management of soil

health, use of healthy seeds and planting material, application of fungicides when required, field sanitation, cultural practices which suppress the disease , use of bio-control agents and growing resistant plant genotypes .

## Different Approaches of Integrated Disease Management System

1. **The combined control approach**: It is a combination of control methods like adjustment in sowing time, seed treatment, use of resistant variety, chemical spray schedule etc. This type of IDM is widely practiced as a package of practice where the occurrence of disease is certain and sure.
2. **The surveillance based approach**: It is an advanced IDM approach based on crop health monitoring and surveillance, and takes into account the economic threshold levels or economic damage levels.
3. **Advanced integrated disease management system**: It involves the high input technology like computer supported forecasting, remote sensing, scouting, multiple pathogen thresholds, information on life cycle of pathogens, epidemiology of diseases, environmental factor and knowledge based decision making.

Main components of integrated disease management (IDM) are host resistance, induced systemic resistance, genetically improved plants, cultural practices, physical methods, plant nutrition, biological control, use of pesticides of plant origin and judicious use of chemicals

### 1. Host resistance

Resistant varieties can be the simple, practical, effective and economical method of plant disease control. Apart from ensuring protection from diseases, they can also save time, money and energy spent on other methods of control and avoids environmental pollution with chemicals. They are the only practical method of controlling such diseases as wilts, rusts and others caused by viruses in which chemical control is very expensive and impractical. In low value crops, where other methods are often too expensive, development of varieties resistant to common and important diseases can be an acceptable recommendation for the farmers.

### Advantages

» No adverse effect on environment and man, rather the resistant cultivars put a constant and cumulative effect on pathogen.

- Host plant involves no extra cost to the farmers and does not require inputs and application skills.

**Disadvantages**

- The development of pathogen resistant variety takes a long time (5-10 years).
- Host plant resistance can put a selection pressure on pathogen to the extent that it may lead to the evolution of new biotypes of pathogen.
- Introduction of varieties with resistance to one pathogen leads to the emergence of new pathogen problem because of the absence of competition from the key pathogen.

**2. Induction of host resistance**

Plants actively respond to a variety of environmental stimuli, including gravity, light, temperature, physical stress, water and nutrient availability. Plants also respond to a variety of chemical stimuli produced by soil- and plant-associated microbes. Such stimuli can either induce or condition plant host defence through biochemical changes that enhance resistance against subsequent infection by a variety of pathogens. Induction of host defence can be local and/or systemic in nature depending on the type, source, and amount of stimuli.

The systemic acquired resistance (SAR) is mediated by salicylic acid (SA), a compound which is frequently produced following pathogen infection and typically leads to the expression of pathogenesis-related (PR) proteins. These PR proteins include a variety of enzymes, some of which may act directly to lyse the invading cells, reinforce cell wall boundaries to resist infections, or induce localized cell death whereas, the induced systemic resistance (ISR) is mediated by jasmonic acid (JA) and/or ethylene, which are produced by following applications of some non-pathogenic rhizobacteria. Interestingly, the SA- and JA- dependent defense pathways can be mutually antagonistic, and some bacterial pathogens take advantage of this to overcome the SAR. Pathogenic strains of *Pseudomonas syringae* produce coronatine, which is similar to JA, to overcome the SA-mediated pathway.

Because various host-resistance pathways can be activated to varying degrees by different microbes and insect feeding, it is plausible that multiple stimuli are constantly being received and processed by the plant. Thus, the magnitude and duration of host defence induction will likely vary over time.

### 3. Genetically improved plants

Genes from plants, microbes and animals can be combined and introduced in to the living cells of other organisms, and the organisms that have genes from other species inserted into their genome are called transgenics. Production of disease resistant transgenic plants has been achieved by this method; certain genes are inserted in to plant genome that confers resistance to pathogens such as viruses, fungi and insects. These transgenic plants reduce the pesticide use and thereby provide environmental benefits while reducing farmers cost. Genetically modified plants are generally used to control the viral diseases, e.g., a transgenic papaya cultivar 'Rainbow' has been developed which is resistant to papaya ring spot virus in the US.

### 4. Cultural practices

Different cultural practices like crop rotation, mulching, tillage, different soil amendments, soil solarization, soil sterilization, change in date of sowing, plant spacing etc. when applied alone are able to control diseases up to some extent; but when these cultural practices are combined with each other, they not only control the diseases but also increase the yield of crops.

The inter-cropping of maize and sorghum with peppers serves as barriers against the aphid vectors of pepper veinal mottle virus and reduces the virus spread. Soil solarization for 40 days along with the addition of cabbage, cauliflower, broccoli and sarson leaf residues controlled the gladiolus wilt (*Fusarium oxysporum* f.sp. *gladioli*) by 74.6% whereas soil solarization (for 40 days) alone reduced the gladiolus wilt by 67.3% compared to the un-solarized control.

### 5. Physical methods

Solar heat treatment of the water soaked wheat seed in May-June for 5-6 hours provides good control of loose smut of wheat. Most of the post harvest diseases can be avoided by irradiation, refrigeration, Controlled Atmosphere Storage etc. Soil solarization has been used to control soil borne diseases caused by otherwise difficult to control fungi, e.g., *Rhizoctonia solani*, *Fusarium* spp., *Sclerotium* etc .

It has been used in raising disease free nursery in tropical and subtropical climatic areas. It also provides excellent weed control. Hot water treatment of cabbage seed at 52$^{o}$C for 15-20 minutes controls black rot disease (caused by *Xanthomonas campestris* pv. *campestris*).

## 6. Plant nutrition

The nutrition of crop plants has direct effect on the diseases, and is an important component of integrated disease management (IDM). Both deficient and over-nourished plants invite high incidence of diseases as well as loss in yield and quality of produce and products.

The amount, proportion, time and method of application of fertilizers affect the metabolism of plants and thus occurrence and severity of diseases. Fertilization with both P and K significantly reduces the leaf rust damage and powdery mildew infection in wheat. The deficiency of macronutrients may also affect the incidence of many diseases.

Potassium (K) plays an important role in survival of crop plants under environmental stress conditions. Potassium also affects the reaction of plants to pests or diseases by having direct effect on the pathogen number, development, multiplication, survival, vigour and length of life cycle.

## 7. Biological control

Biocontrol agents are used as a core component of integrated disease management system. The science and art of using living organisms as biocontrol agents is an important component of environment friendly disease management procedures. These biocontrol agents are of enormous value in integrated diseases management for sustainable agriculture where they often replace the need of fungicides. The biocontrol agents either suppress the pathogen growth either by the antibiotic production, hyperparasitism or by competition.

Various biocontrol agents used in control of various diseases are *Bacillus subtilis*, *Pseudomonas fluorescens, Gliocladium* spp., *Trichoderma* spp., *Chaetomium globosum, Pseudomonas cepacia*, *Bacillus cereus, Agrobacterium radiobacter* etc. *Trichoderma viride* is the most important and versatile biocontrol agent used for the control of a number of plant pathogens *like Rhizoctonia solani* and *Sclerotium rolfsii* which are otherwise difficult to control by other methods.

*Ampelomyces quisqualis* and *Darluca* spp. hyperparasitize powdery mildew and rust fungi, respectively, and therefore exploited for their biological control. *Agrobacterium radiobacter* K-84 strain has been used against crown gall disease world over.

**8. Use of pesticides of plant origin**

- Pesticides of plant origin are derived from plant parts and their genes are also used to transform crops to express resistance to insect, fungal and viral attack.
- The plant parts and their extracts with antifungal properties play an important role in plant disease management.
- Garlic (*Allium sativum*) has a long history of reputed value and actual use for its medicinal, antimicrobial and pesticidal properties.
- The growth of *Rhizoctonia solani* can be reduced with ethanolic extracts of Eucalyptus sp., *Chenopodium ambrosioides*, *Lippia alba*, *Aegle marmelos* and *Cestrum diurnum* leaves.
- The seed extract of Piper nigrum was found to be effective against *R. bataticola*.

**Judicious use of fungicides**

- Chemicals have been used successfully to combat the ravages of these diseases for many years.
- Fungicides with different modes of action like protective (broad spectrum fungicides), post infection activity (EBI), pre- symptom and post symptom (benzimidazoles and triazoles) may be used for controlling a wide array of plant diseases ravaging various crops.
- The over-use of these chemicals resulted in water pollution, residues on food and fruit crops, effect on non- target organisms and development of resistance in pathogens against the chemicals have drawn the attention toward the rational use of fungicides by including monitored control strategies and cultural practices.

## Types of Integrated Disease Management

### i) Integration of cultural and chemical control

- The integration of chemicals and cultural practices (including improved cultivars) has resulted in a continuous supply of fresh watermelons, reduced diseases caused by *Colletotrichum lagenarium*, *Pseudomonas syringae* pv.

*Lachrymans* and *Pseudoperonospora cubensis*.

- The covering the tomato nursery seedlings with nylon net for 25-30 days plus 4 sprays of monocrotophos at 10-days intervals after transplanting, delayed the spread of Tomato leaf curl virus for 3-5 weeks and increased tomato yields.

**ii) Integration of chemical and biological control**

- Bio-control agents such as *Pseudomonas fluorescens, Trichoderma viride, T. harzianum, Bacillus subtilis, Pseudomonas putida, P. cepacia, Talaromyces flavus, and Agrobacterium radiobacterstrain* K 84 etc. can be used with integration of chemicals for the effective control of certain diseases.

**iii) Integration of resistance, cultural, biological and chemical control**

- The integration of cultural practices (crop rotation, good farm hygiene procedures, quarantine), fertilizers, soil fumigation and solarization, pesticides (fungicide transplant dips, soil drench, soil incorporations, seed treatments, trace elements and surfactants), resistant cultivars and biocontrol agents are used for the control of club root (*Plasmodiophora brassicae*) of vegetables.

**IDM module for soil borne diseases**

The diseases that are caused by pathogens which persist (survive) in the soil matrix and in residues on the soil surface are defined as soil borne diseases. Thus the soil is a reservoir of inoculum of these pathogens, the majority of which are widely distributed in agricultural soils. Soil borne diseases are difficult to control because they are caused by pathogens which can survive for long periods in the absence of the normal crop host, often have a wide host range including weeds, chemical control often does not work well, is not practical or is too expensive and it is difficult to develop resistant varieties of plants. The effective control of the soil borne diseases is possible only through detailed study on survival, dissemination of soil borne pathogens; effect of environmental conditions role of cultural practices and host resistance and susceptibility will play a major role in disease management.

**Predominant soil borne pathogens**

**Fungi:** *Sclerotium* rolfsii, *Rhizoctonia solani, Fusarium sp, Pythium, Phytophthora* etc.

**Bacteria:** *Erwinia, Raltsonia, Rhizomonas, Agrobacterium, Streptomyces* etc.

## Management of Soil Borne Diseases

An effective disease management option must be economical: that is, the value of the crop saved must exceed the cost of control. For this reason, assessments of disease incidence, disease severity, and potential crop loss are key factors when considering control strategies. The careful, regular monitoring of fields and the thorough examination of symptomatic plants are essential steps. The timing of control measures is also critical. however, so it usually is best to integrate multiple management options (e.g., planting resistant varieties, following beneficial cultural practices, and applying disease-control materials).

### Cultural control

### Fertilizer application

» Application of fertilizers along with irrigation improves the overall plant health and thereby reduces the impact of severity of diseases.

» Application of ammonium bicarbonate reduce the viability of sclerotial bodies of *S. rolfsii*

» Application of phosphatic fertilizers also influences the host resistance by increasing the production of phytoalexins

» Management of *Pythium* and *Phytophthora* by application of phosphoric acid.

» Application of gypsum reduces the incidence of *Macrophomina* in groundnut.

### Providing good soil drainage and good air circulation among plants

Management of irrigation to minimize water dispersal of soil borne pathogens and monitoring disease incidence by avoid spread to other areas are practices that have no apparent involvement with soil microbes. When diseases occur timely removal of dead or infected plants can reduce the potential for inoculum build up.

» Good soil drainage reduces the number and activity of certain oomycetes pathogens (eg., *Pythium*) and nematodes.

» Flooding fields for long periods or dry fallowing may also reduce *Fusarium*, *Sclerotinia sclerotiorum*, and nematodes

» Irrigation also helps to reduce the soil borne disease charcoal rot caused by *M. phaseolina*.

## Crop rotation

Generally, soil borne pathogens survive in the soil and plant debris up to several years. Crop rotation will be helpful to control the soil borne inoculum because if the host is not present for particular number of years then the amount of inoculum will be reduced. Satisfactory control through crop rotation is possible with pathogens that are soil invaders, crop rotation can still reduce populations of the pathogen in the soil (e.g., *Verticillium*). In some cropping systems the field is tilled and left fallow for a year or part of the year.

## Tillage practices

Soil preparation before sowing helps in reducing pathogen population by either burial of inoculum deep into the soil or its drying in the top exposed layers. Deep ploughing of crop residues which harbor the pathogen is more effective in reducing this important source of infection. Sub-soiling prior to planting was found to increase the green pea yields of root rot susceptible and tolerant cultivars planted in the soil infested with *F. Solani* f.sp. *pisi* and *Pythium ultimum*. The integrated use of tolerant cultivars and cultural practices which reduce the soil compaction could economically reduce the effects of pea root rot in sandy loam soils.

## Soil amendments

Application of organic amendments like saw dust, straw, oil cake, etc., will effectively manage the diseases caused by *Pythium*, *Phytophthora*, *Verticillium*, *Macrophomina*, and *Aphanomyces*. Beneficial microorganisms increases in soil and helps in suppression of pathogenic microbes. For example, application of lime (2500 Kg/ha) reduces the club root of cabbage by increasing soil pH to 8.5. Similarly application of sulphur (900 Kg/ha) to soil brings the soil pH to 5.2 and reduces the incidence of common scab of potato cause by *Streptomyces scabies*. Application of castor cake and neem leaves helps to reduce the foot rot of wheat.

## Soil Solarization

When clear polyethylene is placed over moist soil during sunny summer days, the temperature at the top 5 centimetres of soil may reach as high as 52°C compared to a maximum of 37°C in un-mulched soil. If sunny weather continues for several days or weeks, the increased soil temperature from solar heat, known as solarization, inactivates (kills) many soil borne pathogens such as fungi, nematodes, and bacteria near the soil surface, thereby reducing the inoculum and the potential for disease.

*Verticillium* wilt, Fusarial wilt will be controlled by soil solarization. Bacterial canker of tomato, caused By *Clavibacter michiganense*, is also reduced by this method. Sub-lethal doses of temperatures due to soil solarization also make the pathogen propagules more susceptible to attack of biocontrol agents.

### Biological control

Biological control of pathogens, *i.e.*, the total or partial destruction of pathogen populations by other organisms, occurs routinely in nature. There are, for example, several diseases in which the pathogen cannot develop in certain areas either because the soil, called suppressive soil, contains microorganisms antagonistic to the pathogen or because the plant that is attacked by a pathogen has also been inoculated naturally with antagonistic microorganisms before or after the pathogen attack. Sometimes, the antagonistic microorganisms may consist of avirulent strains of the same pathogen that destroy or inhibit the development of the pathogen, as happens in hypovirulence and cross protection. In some cases, even higher plants reduce the amount of inoculum either by trapping available pathogens (trap plants) or by releasing into the soil substances toxic to the pathogen.

## Suppressive Soils

Several soil borne pathogens, such as *Fusarium oxysporum* (the cause of vascular wilts), *Gaeumannomyces graminis* (the cause of take-all of wheat), *Phytophthora cinnamomi* (the cause of root rots of many fruit and forest trees) and *Pythium* spp. (a cause of damping-off), develop well and cause severe diseases in some soils, known as conducive soils, whereas they develop much less and cause much milder diseases in other soils, known as suppressive soils. The mechanisms by which soils are suppressive to different pathogens are not always clear but may involve biotic and/or abiotic factors and may vary with the pathogen. In most cases, however, it appears that they operate primarily by the presence in such soils of one or several microorganisms antagonistic to the pathogen. Such antagonists, through the antibiotics they produce, through lytic enzymes, through competition for food, or through direct parasitizing of the pathogen, do not allow the pathogen to reach high enough populations to cause severe disease. Numerous kinds of antagonistic microorganisms have been found to increase in suppressive soils; most commonly, however, pathogen and disease suppression has been shown to be caused by fungi, such as *Trichoderma*, *Gliocladium* and *Chaetomium*, or by bacteria of the genera *Pseudomonas*, *Bacillus*, and *Streptomyces*. Suppressive soil added to conducive soil can reduce the amount of disease by introducing microorganisms antagonistic to the pathogen. For example, soil amended with soil containing a strain of a Streptomyces species antagonistic to *Streptomyces scabies*, the cause of potato scab, resulted in potato tubers significantly free from potato scab. Suppressive, virgin soil has been used, for example, to control *Phytophthora root* rot of papaya by planting papaya seedlings in suppressive soil, which was infested with the root rot *Phytophthora palmivora*.

## Chemical Control

Chemical pesticides are generally used to protect plant surfaces from infection or to eradicate a pathogen that has already infected a plant. A few chemical treatments, however, are aimed at eradicating or greatly reducing the inoculum before it comes in contact with the plant. They include soil treatments (such as fumigation), disinfestation of warehouses, sanitation of handling equipment, and control of insect vectors of pathogens.

Soil Treatment with Chemicals Certain fungicides are applied to the soil as dusts, liquid drenches, or granules to control damping-off, seedling blights, crown and root rots, and other diseases. In fields where irrigation is possible, the fungicide is sometimes applied with the irrigation water, particularly in sprinkler irrigation. Fungicides used for soil treatments include metalaxyl, diazoben, captan, and chloroneb, although the last two are used primarily as seed treatments.

» Chemicals in plant disease are used to create the toxic barrier between the host surface and pathogen.

» These are applied in the soil as pre and post plant applications. Generally these treatments are being given in high value cash crops.

» Applied as soil fumigation, soil drenching and seed treatment.

» Fungicides like prothiocarb, propamocarb and metalaxyl are useful to control the Oomycetes pathogens.

» Fosetyl – Al is the fungicide which controls the soil borne pathogens when it is used as foliar spray.

» All the fungicides significantly increased seed germination and plant size and reduced seedling mortality and root infection by *F. solani* in bottle gourd, bitter gourd and cucumber.

## Host Plant Resistance

Growing of resistance plants is one of the most effective and economical method. Host plant resistance not only reduces the crop losses but lessens the expenditure incurred on disease control as well as reduces the pollution hazards.

Management of soilborne diseases is most successful and economical when all the required information pertaining to the crop, disease affecting it, history of these in the previous years, resistant levels of the host and environmental conditions to prevail is available. Combination of disease management practices may have additive or synergistic effects and such an approach is especially desirable in the case of soil borne diseases.

### IDM module for airborne diseases

Air borne diseases: - The micro-organisms are spread through air and attack the plants causing diseases. E.g. Blight, rust, powdery mildew. Because airborne nature of pathogens can be spread long distances on the wind, they can cause devastating losses, particularly on crops that are planted over large regions.

The main emphasis in research and development to combat foliar diseases is on host resistance and chemical control where ever applicable, and quite often these components of disease management were practiced in isolation to each other. Recently a shift in scientific thinking and practice in the management of foliar diseases has been seen and greater emphasis was on identifying, evaluating, and integrating location specific components of integrated disease management (IDM). The location specific IDM of foliar disease is primarily based on host plant resistance (HPR) or genetic resistance; additionally other components of diseases management. In some environments, IDM may require a single component used alone (usually HPR) or in combination with one other component (such as fungicide seed treatment) to adequately combat diseases of foliar disease.

The components of IDM employed in the foliar disease management are listed as follows:

- Host plant resistance (HPR),
- Disease modeling (prediction) for avoidance of high risk or disease pressure,
- Chemical sprays (fungicides, pesticides),
- Biological control, and
- Cultural (agronomic) practices (sowing dates, plant population etc.).

**Host plant resistance (HPR):** It utilizes in – built mechanism to resist various activities of pathogen. The infection or subsequent damage by pathogen can be rendered ineffective through genetic manipulation or by chemotherapy. The host resistance can also be induced by use of certain biotic and abiotic factors. Plant breeding techniques include selection, mutation and hybridization have helped in developing crop varieties resistant to specific pathogen or group of pathogens. Use of biotechnological tools such as tissue culture, genetic engineering and protoplast fusion are being used to develop resistant cultivars of various economically important crops.

**Avoidance** It involves avoiding disease by planting at time when, or in areas where inoculums is absent or ineffective due to environmental conditions. The major aim is to enable the host to avoid contact with the pathogen or to ensure that the susceptible stage of the plant does not coincide with favourable conditions for the pathogen. The main practices under avoidance are choice of geographical area, selection of the field, choice of sowing/ planting time, selection of seed and planting material, short duration / disease escaping varieties and modification of agronomic/cultural practices. The potato cultivation at high altitude is relatively free from viruses; as prevailing environmental conditions do not permit the build up of vector populations. Similarly, early planting of potato or wheat, in indo Gangetic plains may escape late blight or stem rust damage respectively.

**Chemical control** Chemical control is widely used to maintain green leaf area and increase grain yield. Fungicide treatment has been found to be effective when the infection level is visually more than 5% of the leaf area. The economical benefit should be achieved from proper timing of reduced fungicide doses, which give substantial increases in net yield and cost-effectiveness. Another strategy is the proper choice of fungicide; its dose and application time are important in achieving economic efficacy. Carbendazim applied as a soil drench at 2000Ppm, 10 days before inoculation of pigeonpea plants with *Fusarium udum* controlled the wilt. Griseofulvin and bulbiformin, two antibiotics were also found very effective against *Fusarium udum*. Seed treatment is one aspect of crop management. It is an advanced and economic delivery system to protect the genetic potential of the seed against diseases from the moment of sowing and also partial replacement of the conventional foliar application.

**Biological control:** Success in using microorganisms against plant pathogens started with the control of crown gall with Agrobacterium radiobacterK84 and that of seedling blights caused by *Pythium* and *Rhizoctonia* with *Trichoderma harizanum*, *Gliocaladium virens* and *Streptomyces griseus*. However, the use of naturally occurring bio-control agents (antagonists) of plant pathogens can be traced back to many centuries through the traditional practice of crop rotations that primarily permit the reduction of pathogens' inoculum potential. Biological control remains an attractive possibility for many soil borne plant pathogens even it can also useful for the foliar pathogen also. It has been found at least partially successful for many wilt causingfusaria. Introduction of the antagonist along with planting material has been reported to be more economical and effective method of biological control. Antagonists when applied to seeds were found to colonize the rhizosphere and offer protection against several soil borne pathogens. Significant reduction in wilt disease was also obtained in cotton, melon and wheat crops with seed treatment of *Trichoderma harziaizum*. Seed treatment with Trichoderma also afforded better protection against crown rot of tomatoes, in fields naturally infested with *Fusarium oxysporum f.sp. lycopersici*. In early studies, *Bacillus subtillis* was identified as a potential antagonist to have good potential for biological control of several plant pathogens. *Aspergillus nidulans* has also been identified as a possible biocontrol agent in slightly acidic to alkaline soil at higher temperatures. Host plant resistance is the main stay of integrated disease management in any crop, as it is a cheap and safe method of disease control. Soil saprophytes and antagonists such as *T. viride* and *A. niger* were among the mycoflora of the wilt resistant cultivar ICP 8858, while the mycoflora of the susceptible cultivar ICP 85 18 showed a predominance of F. udum during all the stages of plant growth.

**Cultural control** This refer to the manipulation of crop environment in order to make it less favourable for the pathogen, through the adoption of measures such as adjusting planting time, plant spacing, season, irrigation, green manuring, crop rotation and crop combination either alone or in combination with other techniques. Cultural control methods not only serve in promoting the healthy growth of the crop, but are also effective in directly reducing inoculum potential (pruning, roguing, crop rotation, ploughing, etc.) and in enhancing the biological activities of antagonists. The practice of crop rotation, intercropping and multiple cropping have long been regarded as successful means of reducing diseases and pathogen populations. Amendments in the form of plant debris, green manure, farmyard manure, compost, oilcakes, fertilizers are known to improve crop productivity by improving nutrient status and soil tilth. Further, these materials can either increase or decrease plant pathogen levels and thereby disease intensity. Among the plant nutrients, potassium has significant role in governing resistance to plant diseases.

**IDM module for seed borne diseases**

The following points highlight the top five control methods against seed borne pathogens. The control methods are: 1. Regulatory Method 2. Cultural Methods 3.

Physical Methods 4. Chemical Methods 5. Biological Methods.

**1. Regulatory method:** There are certain federal and state laws which regulate the conditions for cultivation of crop and their distribution between states and countries. This helps preventing the import and spread of pathogen into country or individual states. Such regulatory methods are enforced by means of quarantines, inspection of plants in field or warehouses, and occasionally by voluntary or compulsory eradication of certain host plants.

i. **Plant quarantine:** Plant quarantine as a practice covered two basic principles of disease management exclusion and eradication. When germplasm is regulated by quarantine the entry of organism and seeds with infection is prevented by inspection and treatment or the host is banned or otherwise restricted. The plant and their products must be imported only from disease- free areas. Even if the material is already inspected by the quarantine services of the exporting country, it should be rechecked at the point of import. Special precautions are needed when cultures of pathogenic fungi, bacteria etc. are exchanged for scientific purposes.

ii. **Inspections/Certification:** Several voluntary inspection and certification systems are also in effect in various areas in which appreciable amount of seed, seedling nursery stock, potato seed tubers etc. are produced. Growers interested in sale of these materials submit for voluntary inspection and/or indexing of their crop in the field and in storage by regulatory agency.

iii. **Use of pathogen free seeds/propagating material:** Crop plants attacked by vectored viruses, mycoplasmas, fungi, bacteria and nematodes can be protected from disease by this method. It must be ensured that the propagating materials (seed, tubers, buds, bulbs, grafts, root stocks, corms, cuttings, rhizomes etc.) are free from pathogens.

**2. Cultural methods:** Adjustment of crop management procedures has been an age old practice with the farmers for prevention of losses in crops due to diseases and other causes. It is an integral part of subsistence agriculture in developing countries. Cultural practices are now being considered as essential back up procedures for management of resistant varieties and also for chemically protected crops.

For development of a disease, contact between the host and the parasite must occur in an environment that is favourable for the pathogen and pathogenesis. Suitable modification in cultural practices can modify the environment that is not favourable for the pathogen but favourable for the host.

On this basis disease control by cultural practices is mainly preventive. Many practices reduce the density and activity of the inoculum. Precautions taken under avoidance are also mainly cultural practices. A large number of fungal, bacterial and virus pathogens are transmitted through true seed or vegetative propagating material. For effective disease control this source of primary inoculum must be taken care of.

Although the infested or infected propagating material can be made pathogen free by chemical or physical treatments, production of such seed in the field is the first and important step. Following practices are followed to produce and use pathogen-free seed material.

i. **Dry climate for seed production**: Control of seed-borne diseases favoured by wet climate can be achieved by raising the crop in dry areas. Some examples are anthracnose of bean (*Colletortichum lindemuthianum*), anthracnose of cucurbits (*Colletortichum lagenarium*), Ascochyta blight of pea (*Ascochyta* spp.). For producing seed of such crops dry areas are preferred where leaf wetness is avoided. Reasonably good dry climate can be created in wet areas through management of crop canopy facilitating air circulation and entry of sun rays.

ii. **Isolation distance for seed plots:** Separation of seed plots from sources of inoculum helps in production of healthy seed. In the production of certified seed, a particular distance between plots is mandatory.

iii. **Inspection of seed plots:** Periodical inspection of the crop being raised for seed or orchards producing grafts and seedlings of fruit trees for distribution is an important step. Eradication of diseased plants or plant organs immediately follows the inspection. If the crop is badly diseased the plot is rejected for seed. The procedure is followed in production of seed tubers of potato.

iv. **Drying and aging of seed:** Some pathogens do not tolerate drying of seeds. Viability of some seed is longer than the pathogen present in them. Thus prolonged storage often eliminates the pathogen from the seed. *Fusarium solani* f.sp. *cucurbitae*, infecting different cucurbits, is internally seed-borne. When the infected seed is stored for two years before sowing the fungus is killed. In such method proper conditions for storage must be maintained to avoid harm to the seed.

v. **Cleaning of seed:** Sclerotia and oospores of many fungal pathogens and cockles or cysts of nematodes may be present in the debris mixed with the seed. Common examples are white blisters of crucifers, cyst nematode of sugar beet, and ear cockles of wheat. Cleaning of seed is done by hot air blast that removes the dust also and by hand. In hand cleaning the seed is submerged in a 20% common salt solution. The debris and nematode cysts or cockles float on the surface and can be skimmed off by hand.

vi. **Thermal and chemical treatment of seed:** Heat or chemical treatment of seed before storage is a part of cultural practices for healthy seed production. Chemical seed treatment is a compulsory step in the production of certified seed. Thermal treatment of seed is favored in those cases where the pathogen is deep seated and ordinary protective fungicides control reach the pathogen. Many systemic fungicides are capable of reaching the internal tissues. Treatment of seeds with vitavax and thiram are the examples of seed treatment for eradication of the pathogen. Bare root dip treatment of seedlings with nematicides is practiced to control root knot and other nematodes.

vii. **Site and treatment of nursery beds:** Diseases like club root of cabbage, root knot of tomato are generally carried by seedlings or grafts from the contaminated nurseries. The nursery site should be chosen with care avoiding locations near infested fields and the soil should be periodically treated with heat or chemical. Soil solarization is feasible method for nursery soil treatment. The other method is to burn a heap of farm trash over the beds. Soil fungicides are also available for chemical treatment.

viii. **Adjustment of harvesting time of the crop:** Time of harvesting affects cleanliness of the seed. Delayed harvesting of grain crops in temperate regions gives the pathogens more time for contaminated the seed. Grain crops harvested in wet weather often produce contaminated seed. Harvesting of potato when the leaves are still green allows the late blight pathogen to contaminate tubers which carry it to the next season. Such situation can be avoided by suitable alteration in the timing of harvest of the crop.

**3. Physical methods:** Different physical methods employed for reduction or elimination of primary inoculum are as follows:

i. **Hot water treatment of seeds and other parts:** Hot water is widely used for control of seed borne pathogens especially bacteria and viruses also fungi. Temperature and period of treatment will vary with the infection or pathogen concerned. In hot water treatment seeds are to be presoaked for four hours at 20-30°C, during which period dormant mycelium develops activity and becomes more vulnerable to exposure in hot water at 50-52°C for a few minutes. Seeds after treatment are to be dried very carefully before they can be use for sowing. This method is cumbersome. Small quantities can be treated at a time. Besides, temperature has to be exactly maintained during the period of treatment.

ii. **Hot air treatment:** Hot air treatment is less injurious to seeds and easy to operate but also less effective than hot water. It is use the for treating sugarcane stalk on commercial scale for control Ratoon-stunting Disease (RSD). In this method hot air treatment at 54°C for 8hour effectively eliminate pathogen without impairing germination of buds. Similarly grassy shoot disease of sugarcane has been controlled by hot air at 54°C for 8 hour.

iii. **Solar heat treatment**: Solar heat treatment is effective in controlling both seed borne and soil borne diseases.

Seed-borne diseases: Solar heat treatment controls effectively the loose smut of wheat (*Ustilago nuda tritici*). In this method the seed is soaked in water for four hours (8 a.m. to 12 noon) on a bright summer day. After this presoak, that seed is dried in the sun for four hours from 12 noon to 4 p.m. *Ascochyta rabiei* the casual organism of Ascochytosis of chick pea survives in seed. The seeds were exposed to bright sun light during the last week of May and the first week of June. The seeds were spread on cemented floor from 8 a.m. to 4 p.m., daily for 15 days. Direct exposure of seeds on cemented floor reduced the recovers of the fungus.

**4. Chemical methods:**

**Seed treatment by chemicals:** It is a known fact large number of disease/seed borne pathogen carried/introduced through the seeds. Seed treatment is a process of application of chemical or protectants (with fungicidal, bactericidal, nematicidal insecticidal properties) to seed, that prevent the carriage of diseases and also insects' causing pathogens in/on the seeds. Seed treatment also enables the seed to overcome seedling infection by soil borne fungi. The application of chemicals to seeds before planting in other words seed treatment has two purposes:

i. Control of disease caused by seed borne pathogen/seed infection.

ii. Protection of germinating seed or seedling from the attack of soil borne pathogen.

Appropriate treatment of seeds can get rid of the seed borne pathogen and can control, to a large extent diseases that would otherwise/harmful result. Besides, incorporation of protective chemical on the surface of seed can reduce the change of infection, consequently harmful effect of many soils borne pathogen which are capable of causing decay of seeds, pre- or post-emergence of damping off or infection in seedlings.

**5. Biological methods:**

Bacterial and fungal antagonists may be more effective when applied to seed than applied to soil because of their proximity, in large numbers, to the infection court. Seeds are vulnerable to seed borne and soil borne pathogens, and the period of protection not be long. The first commercial use of an organism to control a plant disease in soil is *Agrobacterium radiobacter* to control crown gall in rosaceous hosts. *A. tumefaciens* strain 84 produces an antibiotics called "agrocin 84," which is one of a group of highly specific antibiotic known as nucleotide bacteriocins.

Selected examples of root diseases control by application of antagonistic bacteria or fungi to seeds. Seed treatment, usually directed against soil borne pathogens, can also affect seed- borne storage and field fungi (fungi that infect seeds before harvest). *Chaetomium globosum* to corn kernels before placing them on an agar medium, and this application reduced the percentage kernels infected with both field and storage fungi.

**IPM module for vector borne plant diseases**

Epidemiology of vectored plant pathogens involves the plant, the pathogens, the vectors, and the environment, all interacting in various ways. Often, an understanding is needed of seasonal cycles of host plants, pathogens, and vectors. For example, pathogens and vectors important to an annual crop may have non-crop reservoirs between harvest and re-planting. Vectors may overwinter in the crop, or on alternate host plants. The host range of the pathogen may determine whether inoculum control is feasible or not. Some pathogens are transmitted via plant propagation, and others are not. The epidemiology of vectored plant pathogens often is complex and an integrated approach to management is needed.

**Chemical control**

Chemical control of vectors will limit spread of vectored plant pathogens if two conditions are met. First, the vector being controlled must be a colonizer of the crop being treated. Some plant viruses are transmitted by transient flying insects. In these cases, chemical control has a poor record. Second, most of the spread must come from within the treated area (secondary spread). For the most part, insecticides simply prevent the buildup of populations of insects within a treated area. Most pesticides will not kill an immigrant insect before it has a chance to transmit a pathogen. Thus, if there is an infected field nearby with a high population of vectors, pesticide treatment may not be very effective in preventing infection from primary spread. Pesticide treatment has a good track record for control of certain luteovirus diseases such as potato leafroll and barley yellow dwarf, spread by colonizing aphids.

Bhendi Yellow vein mosaic – whitefly control: Spray azadirachtin 0.03 WSP @ 5 g/10l or methyl demeton 25 EC @ 1.6 ml/l or thiamethoxam 25 WG @ 2 g/lit to kill the insect vector.

Tomato spotted wilt virus - thrips vector control: Spray cyantraniliprole 10.26 OD @ 1.8 ml/l or thiamethoxam 70 WS @ 6ml/10 l to control thrips vector

**Biological control**

The use of biological control for management of vectored pathogens has a mixed review. Obviously, fewer vectors is better; however, sometimes the economic threshold for vectors is so low that it is not achievable through biological control. Sometimes, the presence of natural enemies evokes scatter responses in vector prey. This can actually cause an increase in pathogen transmission.

Total dependence on biological control for a vectored pathogen in a perennial crop is risky. Biological control inherently fluctuates between high populations of pests and high populations of natural enemies. If pests are not vectors, the crop often can stand temporary high pest populations, but if the main concern is pathogen transmission, the entire crop can be lost if populations fluctuate in favour of the pest. Similarly, often a grower will have to spray for another pest. The pesticide may kill the natural enemies of the vector, resulting in an increase in transmission of the pathogen and destruction of the crop.

Sometimes disruption of existing biological control can result in an increase in transmission of a plant pathogen. Increased spraying for late blight (caused by a fungus) in potatoes was linked to a major increase in numbers of green peach aphids. Evidently, populations had been controlled by an aphid pathogenic fungus that was killed by the fungicide applications for late blight. The result was a big increase in incidence of potato leafroll virus (PLRV), transmitted by the aphids.

Biological control of the pathogen is another option. Usually this is done by means of cross protection - infecting a crop with a mild strain of a pathogen that prevents symptom expression of a more severe strain that may be transmitted by an insect later on. Cross protection has worked very well for control of citrus tristeza virus, an aphid transmitted closterovirus, in several parts of the world.

**Host plant resistance**

The efficacy of plant resistance to vector depends on the means of resistance and the mode of transmission. Resistance that prevents feeding or repels the insects can prevent transmission of pathogens spread by feeding. If the resistance merely prevents or slows population growth, it cannot prevent primary spread. It can, however, have some effect on secondary spread.

Resistance to the pathogen probably is the most effective means of controlling vectored plant pathogens. If plant resistance to the pathogen is available, it should be the first line of defense. Complications with host plant resistance can occur if the pathogen evolves strains that can break down the resistance. Also, some crops are notoriously difficult to breed due to difficult genetics or longevity.

Resistance to the pathogen may be the only means of management in some cases. An example is sugarcane mosaic virus. Sugar cane is propagated vegetatively, so the virus is propagated with the crop. Once planted, a crop remains in the same field for several years of production, and planting is staggered throughout the production area. Thus, even if clean planting stock could be found, there is no possibility for an area-wide crop-free (and virus-free) period. The virus is transmitted by transient winged aphids, including species that do not necessarily colonize the sugar cane crop, so pesticide application is not effective. Fortunately, there has been success with mosaic resistant cultivars.

**Cultural control**

Many of the effective management practices for diseases caused by vectored plant pathogens involve some sort of cultural control such as adjusted planting date, pruning, roguing, and removal of volunteer crop plants and other non-crop reservoir hosts of vectors or pathogens.

Adjusting planting dates can minimize crop exposure to vectored pathogens. The mite transmitted viruses are particularly serious because they cause severe yield loss, resulting in total crop failure in some cases. These viruses infect newly seeded winter wheat that is planted near a maturing crop from the previous season, or near infected volunteer grain. These viruses are most troublesome in years when the old crop is slow to mature, and there is overlap between late-maturing cereal crops from the previous season and emergence of newly sown winter wheat. The infective mites are blown from the old crop to the new one. After landing on the new crop, they apparently stay put, because there is little secondary spread in the fall. The mites cannot survive very long off a host plant, so any break in the "green bridge" between old and new crops will prevent infection. As little as 10 days delay in planting can make the difference between crop failure and negligible incidence. Similarly, the aphid-transmitted barley yellow dwarf virus complex largely can be prevented by delay in planting. Other viruses are managed on an area-wide basis by maintaining a crop-free period at some time during the year. For such a policy to work, all growers in the area must cooperate in field clean-up and coordination of planting dates.

Pruning and roguing often are used as a means of management of vectored plant pathogens, especially in perennial crops. The efficacy depends on whether latent infections remain, and if so, whether plants with latent infections are suitable source plants for vectors. In the early stages of an epidemic, there usually will be more plants with latent infections than with visible symptoms. If plants with latent infections can serve as source plants for vectors to acquire the pathogens, and vectors are present, pruning and roguing will not be very effective.

In some cases, pruning actually can eliminate disease. Pierce's disease of grape vines is caused by a xylem limited bacteria called *Xylella fastidiosa*. It moves slowly in the plants. If Pierce's disease is transmitted by small leafhoppers that feed on twigs, winter pruning can eliminate most of the infection. However, if the disease is transmitted by the much larger glassy-winged sharpshooter (*Homalodisca coagulata*), which feeds on larger branches and trunks, pruning is much less effective.

Control of volunteer crop plants may limit or eliminate primary inoculum for newly planted crops. Volunteer potatoes are important sources of virus inoculum in potato seed production areas. Similarly, volunteer grain can be an important reservoir for aphids and barley yellow dwarf at planting time for winter wheat. The volunteer wheat provides a "green bridge" for the viruses and their vectors between harvest of one crop and emergence of the next one.

Other cultural control measures include elimination of weed hosts of vectors or pathogens, use of reflective mulches and paints to repel vectors, and various protective row covers. Quite a bit of work also has been done on the use of windbreaks and barrier crops to protect susceptible plantings.

**Regulatory measures**

Regulatory measures for control of vectored plant pathogens are a very important aspect of management, especially for those pathogens that are transmitted through propagation. Strict sanitation measures for propagative material are common. Other kinds of regulatory measures include crop-free periods, quarantines, and required virus testing.

One of the best ways to prevent vector-borne disease in plants is to keep the disease and the vector out. Production of healthy propagation materials involves regulatory agreements. Potato tubers grown for seed are subject to winter testing for a variety of vector-borne viruses. Standards are much stricter for early generation seed. Citrus trees are propagated vegetatively by grafting, in order to ensure varietal uniformity. Citrus trees used for budwood are required to be tested for citrus tristeza virus every year. Those found to contain severe strains are no longer allowed to be used for propagation purposes. Lettuce mosaic virus and bean common mosaic virus are transmitted by seed as well as by aphid vectors. Some states have regulations in place requiring that seed used commercially in the state be tested and meet standards for virus incidence.

Other regulations are tailor-made for a given situation. Green peach aphids (*Myzus persicae* (Sulzer)) transmit potato leafroll virus (PLRV), which causes an important disease in potatoes. The aphids overwinter in peach and apricot trees.