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Review article

MANAGEMENT OF SOILBORNE DISEASES IN CROP PLANTS: AN OVERVIEW

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ABSTRACT: Soilborne diseases are very critical in realizing the yield potential of improved cultivars in several agricultural crops. Often these diseases are very difficult to manage due to their highly heterogeneous incidence and lack of knowledge on the epidemiological aspects of soilborne pathogens. Soilborne diseases of ancient and modern agricultural crops have always had some impact on growth and productivity. Observations and experience passed down through generations gave rise to cultural practices that reduced or minimized the losses to soilborne and above ground diseases, but it was probably rare that anyone in agriculture claimed to "control" the diseases. The expansion in the crop diversity in agriculture has required parallel expansion of strategies to minimize the soilborne diseases. The effective control of the soilborne diseases is possible only through detailed study on survival, dissemination of soilborne pathogens; effect of environmental conditions role of cultural practices and host resistance and susceptibility will play a major role in disease management.

Key words: Soilborne diseases, Soilborne pathogens, Cultural practices, Chemical control

INTRODUCTION

"The diseases that are caused by pathogens which persist (survive) in the soil matrix and in residues on the soil surface are defined as soilborne diseases".Thus the soil is a reservoir of inoculum of these pathogens, the majority of which are widely distributed in agricultural soils. However, some species show localised distribution patterns. Most often damage to root and crown tissues of the plant is hidden in the soil. Thus these diseases may not be noticed until the above-ground (foliar) parts of the plant are affected severely showing symptoms such as stunting, wilting, chlorosis and death.

Soilborne 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. These diseases are often very difficult to diagnose accurately and the pathogens may be difficult to grow in culture and identify accurately. Because of their microscopic size and non-specific symptoms of an infection, soilborne organisms live out of sight and, generally out of mind of the growers and plant protection workers. The effective control of the soilborne diseases is possible only through detailed study on survival, dissemination of soilborne pathogens; effect of environmental conditions role of cultural practices and host resistance and susceptibility will play a major role in disease management [8].

Biology of soilborne pathogens

Survival: Soilborne pathogens survive assoil inhabitants (survive in soil for relatively longer periods), soil invaders or soil transients (survive in the soil for relatively shorter periods). Soilborne pathogens also survive as non-pathogenic and generally in the form of saprobes (organisms that live on decaying organic matter).Under certain congenial conditions these saprobes will turn into pathogenic form.

Distribution of pathogens in the soil

The horizontal and vertical distribution of soilborne pathogens depends on production practices, cropping history, and a variety of otherfactors. Along a vertical axis, the inoculum of most root pathogens lies within the top 10inches of the soil profile, the layers where host roots and tissues and other organic substrates are found. On the horizontal plane, distribution of inoculum in a field is usuallyaggregated in areas where a susceptible crop has been grown:

Factors that influence the distribution: Many factors in the soil influence the activityof soilborne pathogens and diseases: soil type, texture, pH, moisture, temperature, and nutrient levels are among them. Soils that drain poorly, however, tend to favour the survival and distribution of soilborne pathogens such as *Pythium, Phytophthora*, and *Aphanomyces*. Similarly, *Fusarium* and *Verticillium*wilts can also bemore severe in wet soils than in dry soils. Only a few root diseases are favoured bydrier soils (for example, common scab of potato caused by *Streptomyces scabies*).

PREDOMINANT SOILBORNE PATHOGENS:

Fungi: *Sclerotium rolfsii,Rhizoctoniasolani,Fusariumsp,Pythium,Phytophthora*etc.
Bacteria: *Erwinia, Raltsonia, Rhizomonas, Agrobacterium, Streptomyces* etc.
Nematodes: *Meloidogyne, Heterodera, Longidorus, Paratrichodorus* etc.

Different types of diseases caused by soilborne plant pathogens

Root rots

Soilborne diseases are caused by a diverse group of fungi and related organisms. The most important genera include *Pythium* and *Phytophthora, Rhizoctonia, Cylindrocladium* and *Armillaria* which causes root rots. These diseases are characterised by a decay of the true root system; some pathogens are generally confined to the juvenile roots whilst others are capable of attacking older parts of the root system. Symptoms that are observable include wilting, leaf death and leaf fall, death of branches and limbs and in severe cases death of the whole plant. Some examples of these diseases are shown below.

Rhizoctonia Root Rot Disease:

- Known as damping-off, wire stem, head rot, crown rot
- In older seedling the invasion of the fungusis limited to the outer corticaltissues which develop elongate tan to reddish – brown lesion.
- The region may increase in length and width until they finally girdle the stem and the plant may die.

Stem, collar and head rots:

These diseases are also caused by a diverse group of pathogens including species of *Phytophthora, Sclerotium, Rhizoctonia, Sclerotinia, Fusarium* and occasionally *Aspergillusniger*. The most obvious symptom of these diseases is the decay of the stem at ground level. Quite often this decay can lead to symptoms of wilting, death of leaves and to death of the plant. Some examples of these diseases are shown below.*Phytophthora* spp. for example, can cause diseases such as heart rot of pineapple, blight of potato and tomato and some fruit rots in these conditions. Similarly *Rhizoctonia* spp. can cause leaf blight in maize and head rot of cabbage in warm wet weather.

Wilts

The main species of fungi that cause these diseases are *Fusariumoxysporum* and *Verticillium* spp. The symptoms of these diseases include wilting of the foliage and internal necrosis of the vascular tissue in the stem of the plant. Some species of bacteria can also cause similar types of diseases. Some examples of these diseases are shown below.

Seedling blights and damping off diseases

Various common names are used for diseases of seedlings such as seedling blight and damping-off. The fungi that commonly cause seedling death include *Pythium, Phytophthora, Rhizoctonia, Sclerotium rolfsii* and less commonly *Fusarium* sp. These fungi can infect the seedling during the germination, pre-emergence or post-emergence phases of seedling establishment. In northern Vietnam *Pythium, Rhizoctonia* and *Sclerotium rolfsii* are commonly associated with seedling death of vegetables such as beans, cabbages and other cruciferous crops, cucurbits and tomato.

Pythium Damping –off Disease

The species most often encountered are *Pythiumdebaryanum, P. ultimum, P. aphanidermatum, and P. graminicola*.The disease often occurs in a roughly circular pattern. This is because of the tendency of fungi to grow radically from the point of origin, which is one of the field markers to distinguish the diseases between other factors that cause the same symptoms.

Phytophthora damping-off:

- *Phytophthora*species belong to class Oomycetes, family Pythiaceae.
- *P. cactorum, P. fragaria, P. palmivora, and P. syringae*cause primarily low stem rot, damping – off of vegetables, forest trees, and ornamentals.
- Unlike *Pythium, Phytophthora* is aggressive in warmer soil temperatures (15-23° C), but still cool condition. Flooding, along with warm temperature.
- Initially affected tissue develops a soft, waterybrown rot. Within several days, the affected plantparts may dry.

Management of soilborne diseases

Management of soilborne diseases depends on a thorough knowledge of the pathogen,the host plant, and the environmental conditions that favours the infection. In order for adisease to develop, all three factors must be present. The pathogen (a virulent, infectious agent) must have viable inoculum, such as zoospores, available to infect thehost. The host (a susceptible plant) must be exposed to the pathogen's inoculum, andbe physiologically susceptible to infection. Finally, the environmental conditions must be favourable for the infection of the plant and growth of the pathogen. For example, the soil must be saturated with water for a certain period of time in order for water moulds to develop and infect roots. An understanding of these pathogen-host-environment dynamics will help you devise a disease management strategy.

An effective disease management option must be economical: that is, the valueof 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 thoroughexamination of symptomatic plants are essential steps. The timing of control measures is also critical. Management of a destructive disease such as *Phytophthora* root rotmay require early implementation of appropriate management measures. Besidesbeing economically sound, a management strategy should also be simple, safe, inexpensive to apply, and sufficiently effective to reduce diseases to acceptable levels. Fewmanagement options possess all of these desirable qualities, however, so it usually isbest to integrate multiple management options (e.g., planting resistant varieties, following beneficial cultural practices, and applying disease-control materials).

Management options

Management of soilborne diseases is often difficult. Since there is no silver bullet to control these important diseases, it is always advisable to follow all available methods in an integrated manner to better manage soilborne diseases. The methods include,

- Cultural Practices
- Biological Control
- Chemical Control
- Host plant resistance

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 ofphosphatic 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, Sclerotiniasclerotiorum*, and nematodes.
- Irrigation also helps to reduce the soilborne disease charcoal rot caused by *M. phaseolina*.

Crop rotation

Generally soilborne pathogens survive in the soil and plant debris up to several years. Crop rotation will be helpful to control the soilborne 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**, i.e., survive only on living plants or only as long as the host residue persists as a substrate for their saprophytic existence. When the pathogen is a **soil inhabitant**, however, i.e., produces long-lived spores or can live as a saprophyte for more than 5 or 6 years, crop rotation becomes less effective or impractical. In the latter cases, crop rotation can still reduce populations of the pathogen in the soil (e.g., *Verticillium*) and appreciable yields from the susceptible crop can be obtained every third or fourth year of the rotation. In some cropping systems the field is tilled and left fallow for a year or part of the year.

During fallow, debris and inoculum are destroyed by microorganisms with little or no replacement. In areas with hot summers, fallow allows greater heating and drying of the soil, which leads to a marked reduction of nematodes and some other pathogens. Other cropping systems utilize herbicides and reduced tillage and fallow (Eco fallow).

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 *Pythiumultimum* [13]. 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, Phymatotrichum*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 [14]. 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* [6].
- Application of castor cake and neem leaves helps to reduce the foot rot of wheat [14].
- Incorporation of de-caffeinated waste and water hyacinth against root knot nematode [5].

[15] was conducted a field experiment during 2006–2007 wheat growing season at Baoding, Hubei Province, China, aiming at exploring the influence of different amendment rates of maize straw on winter wheat soilborne diseases induced by *Rhizoctoniacerealis*, *Gaeumannomycesgraminis* and *Bipolarissorokiniana* in field conditions. The results showed that the occurrence of three soilborne diseases tested was significantly different under different amendment rates. During the greening stage and jointing stage, the disease indexes of three soilborne diseases were reduced significantly by treatments at the maize straw amendment rates of 7500 kg ha^{-1} and 3750 kg ha^{-1}. However, disease indexes of wheat common rot and sharp eyespot increased dramatically when the amendment rate increased to 15,000 kg ha^{-1}. At the amendment rate of 15000 kg h^{-1} wheat root vigour and SOD activity decreased, and ion infiltration and cell membrane-lipid peroxidation level increased, respectively. In the meantime, higher amounts of bacteria and actinomycetes were recorded in the 7500 kg ha^{-1} amendment rate treatment, while a higher amount of fungi was recorded in the 15000 kg ha^{-1} amendment rate treatment.

Plant density

- Plant density influences the micro-climate and spread of the diseases. Close spacing raises atmospheric humidity and favours sporulation by many pathogenic fungi.
- Wider spacing reduces the *F.oxysporum*f.sp. *ciceri.*
- Severity of crown rot population in wheat increased due to high plant population.
- High density planting in chillies leads to high incidence of damping off in nurseries.

Weed control

Both host and non-host weeds favour disease development by influencing the factors resulting in more inoculum. This includes shading the soil and serving as organic substrate or food base for infection of the host crop. These also change the crop micro-climate and affect soil microflora. In case of wheat, level of take- all disease was found to be higher in the crop having weed intensity indirectly. Trifluralin, was found to greatly increase the cotton blight (*R. solani*) in Israel as it increased host susceptibility and enhanced the saprophytic activity of pathogen, but the same weedicide has been shown to decrease club root on brassicas in greenhouse experiments in England. Similarly spraying of pea crop with MCPB or MCPA increased root rot severity and quickened the expression of root rot symptoms which was due to stress of herbicide on the plant.

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 soilborne 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*Clavibactermichiganense*,isalso 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.

Growing of cover crops:

- Mustard and *Brassica*sp (Broccoli) helps to reduce the load of soilborne pathogens.
- Cover crops will increase soil microbial diversity by enhancing the soil microflora.
- Create unfavorable conditions.
- The *Brassica* spp with high content of glucosinolates in their tissues and allylisothiocyanate in leaf extracts.
- Effect of the incorporation of leaves and /or roots of *B. Juncea*against *Rhizoctoniasolani* and *Gaeumannomycesgraminis*var. *tritici* and suggested the existence of a complex interaction between these two types of residues.

Biological control

Biological controlofpathogens, 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 apathogen 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. Researchers have increased their efforts to take advantage of such natural biological antagonisms and to develop strategies by which biological control can be used effectively against several plant diseases.

Mechanisms of biological control of plant pathogens

Antibiosis – Inhibition of one organism by another as a result of diffusion of an antibiotic

- Antibiotic production is common in soil-dwelling bacteria and fungi. For example, zwittermicin A production by *B. cereus* against *Phytophthora* root rot in alfalfa

Nutrient competition – competition between microorganisms for carbon, nitrogen, O2, iron, and other nutrients

Destructive mycoparasitism – the parasitism of one fungus by another. Direct contact / Cell wall degrading enzymes/Some produce antibiotics.

Example

- *Trichoderma harzianum*, BioTrek, used as seed treatment against pathogenic fungus

Requirements of successful biocontrol:

1. Highly effective biocontrol strain must
    a. Be able to compete and persist
    b. Be able to colonize and proliferate
    c. Be non-pathogenic to host plant and environment
2. Inexpensive production and formulation of agent must be developed
    a. Production must result in biomass with excellent shelf life
    b. To be successful as agricultural agent must be
        1. Inexpensive
        2. Able to produce in large quantities
        3. Maintain viability
3. Delivery and application must permit full expression of the agent
    a. Must ensure agents will grow and achieve their purpose
4. *Trichoderma spp.* are present in nearly all agricultural soils
5. Antifungal abilities have been known since 1930s
        1. Mycoparasitism
        2. Nutrient competition
6. Agriculturally used as biocontrol agent and as a plant growth promoter

Suppressive Soils

Several soilborne pathogens, such as *Fusariumoxysporum* (the cause of vascular wilts), *Gaeumannomycesgraminis* (the cause of take-all of wheat), *Phytophthoracinnamomi*(the cause of root rots of many fruit andforest trees), *Pythium*spp. (a cause of damping-off), and *Heteroderaavenae*(the oat cyst nematode), develop well and cause severe diseases in some soils, known as **conducivesoils**, whereas they develop much less and cause much milder diseases in other soils, known as **suppressivesoils**. The mechanisms by which soils are suppressive to different pathogens are not always clear but may involve biotic and/or abiotic factors and mayvary 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*, *Penicillium*, and *Sporidesmium*, 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 frompotato scab. Suppressive, virgin soil has beenused, for example, to control *Phytophthora*root rot ofpapaya by planting papaya seedlings in suppressive soilplaced in holes in the orchard soil, which was infestedwith the root rot *Phytophthorapalmivora*.

Mycorrhizal Fungi and Disease Suppression

Among the most beneficial root-inhabiting organisms, mycorrhizal fungi can cover plant roots, forming what is known as a fungal mat. The mycorrhizal fungi protect plant roots from diseases in several ways.

- By providing a physical barrier to the invading pathogen. Physical protection is more likely to exclude soil insects and nematodes than bacteria or fungi. However, some studies have shown that nematodes can penetrate the fungal mat.
- By providing antagonistic chemicals. Mycorrhizal fungi can produce a variety of antibiotics and other toxins that act against pathogenic organisms.
- By competing with the pathogen. By increasing the nutrient-uptake ability of plant roots. For example, improved phosphorus uptake in the host plant has commonly been associated with mychorrhizal fungi when plants are not deprived of nutrients, they are better able to tolerate or resist disease-causing organisms.
- By changing the amount and type of plant root exudates. Pathogens dependent on certain exudates will be at a disadvantage as the exudates change.

Two pot experiments were carried out in the greenhouse at Agriculture Research Center, Giza, Egypt, to study the effect of VAM and *T. viride*as deterrents against *R. solani* and *F. solani*disease on growth and quality of sugar beet [1]. Among all the treatments plants treated with mycorrhiza and *T. viride*recorded higher survival rates in sugar beet plants.

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, pentachloronitrobenzene(PCNB), captan, and chloroneb, although the last two are used primarily as seed treatments. Most soil treatments, however, are aimed at controlling nematodes, and the materials used are volatile gases or produce volatile gases (fumigants) that penetrate the soil throughout (fumigate). Some nematicides, however, are not volatile but, instead, dissolve in soil water and are then distributed through the soil.

- 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 soilborne pathogens when it is used as foliar spray.

[10] conducted an experiment to know the efficacy of fungicides as seed treatment. 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.

Best germination was obtained where infested seed of bottle gourd were treated with Aliette (92%) followed by Benlate (90%), Carbendazim, Ridomil, Mancozeb and Vitavax significantly increased germination by 84-88% as compared to control (78%). Effects of fungicides on plant size were significant but varied. Maximum reduction in seedling mortality was obtained where seeds were treated with Topsin-M (4%) followed by RidomilAliette, Benlate, Carbendazim, Mancozeb and Vitavax. Similarly root infection was significantly controlled by fungicidal treatments but with varied effect. Carbendazim and Topsin-M controlled maximum root infection by 6 and 8% respectively.

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.

- Resistance is of two types:

i) Monogenic (Vertical)

It is also known as race specific or major gene resistance. It is complete and is stable for pathogens having a few pathotypes but breakdown easily in others. In case of cabbage yellows (*F. oxysporum*f.sp. *conglutinans*) monogenic resistance is permanent in nature.

ii) Polygenic (Horizontal):

Also known as race non-specific or quantitative resistance. Polygenic resistance is less effective but generally lasts longer.

Host resistance is most effective when combined with cultural and chemical methods.

Transgenic Approaches

Modern DNA technology has made it possible to engineer transgenic plants that are transformed with genes for tolerance of adverse environmental factors, for resistance against specific diseases, or with genes coding for enzymes such as chitinases and glucanases directed against certain groups of pathogens, such as fungi, viruses, and bacteria, or with nucleic acid sequences that lead to gene silencing of pathogens.

Resistance conferred through specific plant genes

There are numerous crops in which plant genes for specific pathogens have been isolated from resistant plants, transferred into susceptible plants, and expressed in these plants. Provided that all the necessary supportinggenes are also transferred and expressed in the new host, some of the formerly susceptible plants now behave asresistant ones. Such resistant plants are subsequently cloned and multiplied, each producing a distinctive line or variety of plant that is resistant to the specific pathogen. When the resistance gene DRR206 from pea was transferred into canola, the transgenic canola plants exhibited resistance to blackleg disease, caused by the fungus *Leptosphaeriamaculans*, decreased seedling mortality caused by the root pathogen *Rhizoctoniasolani*, and resulted in smaller leaf lesions caused by *Sclerotiniasclerotiorum.*

Transgenic Plants Transformed with Genes Codingfor Anti-pathogen Compounds

Genes coding for several pathogenesis-related (PR) proteins, such as chitinases and some glucanases, have been isolated, cloned, and expressed in plants, thereby interfering with the development of certain groups of pathogens and providing resistance to affected plants. Examples of plants transformed with genes coding for anti-pathogenic compounds include peanut plants transformed with antifungal genes that reduced the incidence of Sclerotinia blight, caused by *Sclerotinia minor*significantly compared to susceptible non-transgenic plants [2], [9].

Management through Remote Sensing

Remote sensing is a science/art that permits us to obtain information about an object/a phenomenon through analysis of data obtained through sensory devices without being in physical contact with that object.

Objectives of remote sensing in Plant Pathology

1. Assessment of disease over a vast area
2. To know the relationship of diseases and environment
3. To know the origin and development of epidemics
4. Quantitative assessment of the disease

Remote sensing techniques of importance to Plant Pathology

1. Aerial photography and 2. Satellite imaging

1. Aerial photography: Aerial photography can detect objects on land over a larger area. Colwell(1956) first used remote sensing technique for monitoring stem rust of wheat. He showed that panchromatic colour and especially infrared aerial photography could be used to detect rusts and viral diseases of small grains and certain diseases of citrus. Later, infrared photography was used in England for late blight of potato. The key to distinguish diseased and healthy parts of a crop is to use appropriate film or filter combinations.

The main film types used are panchromatic, infrared, normal colour and colour infrared. The **infrared** films are preferred because of their superior sensitivity to visible light and to near infrared wavelengths of radiation (700-900 mµ). The colour infrared or Ektachrome Aero Infrared (Camouflage Detection Film) is superior as it can show the difference between diseased and healthy patches of plants in colour. The healthy foliage is highly reflective to the infrared wavelengths and appears red on this film whereas blighted or diseased foliage has low infrared reflectance and does not appear red in the photograph.

2. Satellite Imaging

Weather satellites

Often cyclones create heavy clouds with rains and an anti-cyclone creates a cloudless sky. All these can be effectively monitored by weather satellites. Sequential pictures show the movement of these systems before they arrive in an area. Therefore by monitoring epidemic favouring systems using a satellite, the disease occurrence on the field can be monitored. Ex: The spread and deposition of stem rust pathogen of wheat is influenced by definite synoptic weather conditions called Indian stem rust rules.

Earth resources technology satellites (LANDSAT, 1972, USA)

LANDSAT covers the entire globe every 18 days scanning the same area at a fixed time. The scanned data is compared for any major differences happened within 18 days. Nagarajan utilized LANDSAT infrared spectral bands 6 (0.7-0.8µm) and 7 (0.8-1.1µm) to differentiate healthy wheat crop of India and severe yellow rust affected crop of Pakistan.

Examples: Coconut root rot and wilt, black stem rust of wheat, citrus canker

Advantages of remote sensing

1. Reveals pattern of disease incidence, intensity and development over large area
2. Data generated by remote sensing is amenable to multidisciplinary approach
3. Gives synoptic view of large areas
4. Data generated is on a permanent scale and is unbiased
5. Data acquisition is fast compared to traditional methods and data analysed is effectively utilized.
6. Satellite data (ERTS) obtains information of an area periodically so that the information can be updated
7. It frequently poses questions for ground investigators which cannot be generated by ground parties

In the United States, USDA-ARS employed remote sensing technology for detecting crop disease and assessing its impact on productivity include using CIR photography to identify circular areas affected by cotton root rot, *Phymatotrichumomnivorum*[7] and to estimate yield losses caused by blackroot disease in sugar beets [12]. [3] also demonstrated the potential for aerial video imagery to detect *P. omnivorum*inkenaf, a crop whose tall growth habit makes it almost impossible to survey from the ground. The TIR can provide early, sometimes previsual, detection of diseases that interfere with the flow of water from the soil through the plant to the atmosphere. As an example, [11] found that cotton plants whose roots were infected with the soilborne fungus *P. omnivorum* and sugar beets infected with *Pythiumaphanidermatum* both displayed sunlit leaf temperatures that were 3 to 5°C warmer than adjacent healthy plants. Much more research is required when using remote sensing for identifying specific diseases or when separating them from other causes of plant stress. Hyper spectral techniques are likely to provide some assistance, but coupling existing techniques with weather driven computer models of disease development will probably provide the best approach.

CONCLUSION

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 soilborne diseases which are entirely different epidemiologically. Hopefully, the present situation, which emphasizes the use of integrated disease management practices, will stimulate the development of non-chemical methods of disease management to better manage the soilborne pathogens.

General preventive measures to restrict soilborne diseases occurrence

- Select resistant plant cultivars and certified disease-free stock, then plant them at the right time of year
- Avoid mechanical damage to plants
- When possible, obtain plants in their bare root form; if this isn't possible, remove the potting soil from the root system (removing the unknown soil also gives you the opportunity to inspect the root system)
- Do not over-fertilize; doing so inhibits proper root development

- Management of soil pH—raising the soil pH to 6.5–7 by using nitrate nitrogen in place of ammonical nitrogen, for example will decrease the development of Fusarial Wilt.
- Avoid contamination of the growing medium and purchase quality seed
- Avoid use of low, poorly drained areas for nursery production
- Restrict use of machinery in infested areas, particularly when soil is wet
- Prevent movement of soil from infested to non-infested areas of nursery
- Avoid over watering to puddle or run-off point
- Avoid movement of infected trees within and between nurseries

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