AN INSIGHT INTO THE REGIME OF SOIL BORNE PLANT PATHOGENS

Daliyamol, Merin Babu and G.Rajeev
Corresponding author's email: dmol86@gmail.com

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 soil borne disease. 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 they cause damage to root and crown tissues of the plant that 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 finally death.

Soil borne diseases are difficult to control because they are caused by pathogens which can survive for long period of time in the absence of the normal crop host and often have a wide host range including weeds. These diseases are often very difficult to diagnose accurately. Because of their microscopic size and non-specific symptoms of an infection, soil borne organisms live out of sight and, generally out of mind of the growers and plant protection workers. The effective control of the soil borne diseases is possible only through detailed study on survival, dissemination of soil borne pathogens and effect of environmental conditions. Cultural practices and host resistance and susceptibility can play a major role in disease management.

Biology of soil borne pathogens Survival

Soil borne pathogens survive as soil inhabitants (survive in soil for relatively longer periods), soil invaders or soil transients (survive in the soil for relatively shorter periods). Soil borne 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 soil borne pathogens depends on production practices, cropping history, and a variety of other factors. Along a vertical axis, the inoculum of most root pathogens lies within the top 10 inches 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 usually aggregated in areas where a susceptible crop has been grown.

Factors that influence the distribution

Many factors in the soil influence the activity of soil borne 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 soil borne pathogens such as Pythium, Phytophthora, and Aphanomyces. Similarly, Fusarium and Verticillium wilts can also be more severe in wet soils than in dry soils. Only a few root diseases are favoured by drier soils (for example, common scab of potato caused by Streptomyces scabies).

Predominant Soil borne Pathogens

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

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

Different types of diseases caused by soil borne plant pathogens

Root rots

Soil borne 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 characterized 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 or crown rot. In older seedling the invasion of the fungus is limited to the outer cortical tissues 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. The fungus is responsible for brown patch of turf grass, damping off of pulses, black scurf of potatoes, bare patch of cereals, root rot of sugarbeet, belly rot of cucumber, sheath blight of rice etc.

Stem, collar and head rots

These diseases are also caused by a diverse group of pathogens like Phytophthora, Sclerotium, Rhizoctonia, Sclerotinia, Fusarium and occasionally by Aspergillus niger. 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. Phytophthora 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 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 Fusarium oxysporum 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.

Seedling blights and damping off diseases

Fungi that commonly cause seedling death include Pythium, Phytophthora, Rhizoctonia, Sclerotium and less commonly Fusarium sp. These fungi can infect seedli8ng during the germination, pre-emergence or post emergence phases of seedling establishment. Pythium, Rhizoctonia and Sclerotium are commonly associated with seedling death of vegetables such as beans, cucurbits, tomato, cabbages and other cruciferous crops.

Pythium Damping –off Disease

The species most often encountered are Pythium debaryanum, 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 stem rot, damping off of vegetables, forest trees, and ornamentals. Unlike Pythium, Phytophthora is aggressive in warmer soil temperatures (15-23° C), but still cooler condition; flooding, along with warm temperature. Initially affected tissue develops a soft, watery brown rot. Within several days, the affected plant parts may dry.

Management of soil borne diseases

Management of soil borne diseases depends on a thorough knowledge of the pathogen, the host plant, and the environmental conditions that favours the infection. In order to develop a disease, all three factors must be present. The pathogen (a virulent, infectious agent) must have viable inoculum, such as zoospores, available to infect the host. The host (a susceptible plant) must be exposed to the pathogen's inoculum, and be 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 which facilitates water moulds to develop and infect the 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 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. Management of a destructive disease such as Phytophthora root rot may require early implementation of appropriate management measures. Besides being economically sound, a management strategy should also be simple, safe, inexpensive to apply, and sufficiently effective to reduce diseases to acceptable levels. Few management options possess all of these desirable qualities, however, it is usually 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

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 as it will be reduced due to non availability of the host. 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.

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. Population of beneficial microorganisms will increase in the soil which in turn will help 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 can be controlled by soil solarization. Bacterial canker of tomato, caused by Clavibacter michiganense, can also be 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 in case of 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.

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 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, or 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 conductive 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 sp. antagonistic to S. 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 placed in holes in the orchard 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.

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.

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.

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 supporting genes are also transferred and expressed in the new host, some of the formerly susceptible plants now behave as resistant 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 Leptosphaeria maculans, decreased seedling mortality caused by the root pathogen R. solani, and resulted in smaller leaf lesions caused by Sclerotinia sclerotiorum.

Transgenic Plants Transformed with Genes Coding for 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.

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.

Aerial photography

Aerial photography can detect objects on land over a larger area. Colwell 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 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.

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.

Conclusion

Management of soil borne 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 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 soil borne pathogens.

References:

1. Aly MH, Hussein Manal Y (2009) Vesicular-Arbuscular Mycorrhiza and Trichodermavirideas deterrents against soil-borne root rot disease of sugar beet. Sugar Technology. 11(4): 387-391.
2. Breuhl GW. Soilborne plant pathogens. Macmillan Publishing Company, New York, 368pp.
3. Colwell RN (1956) Determining the prevalence of certain cereal crop dis eases by means of aerial photography. Hilgardia. 26:223-286
4. Davis JR, Garner JG, Callihan RH (1974) Effects of gypsum, sulfur, terraclor and terraclorsuper-x for potato scab control. American Potato Journal. 51(2): 35-43.
5. Singh RS. 2001. Disease management- The Practices. Introduction to Principles of Plant Pathology. Oxford& IBH Publishing Co. Pvt. Ltd. New Delhi. pp. 310
6. Utkhede RS, Guptha VK. 1996. Management of Soil Borne Diseases. Kalyani Publishers. New Delhi.