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Soil Borne Diseases of Vegetable Crops

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Soil borne diseases are among the most destructive elements in crop production. The phase-out of many chemicals and rising awareness towards resistance development, environmental health, and climate change necessitates the quest for alternative suitable management options. Many non-chemical options such as sanitation, legal methods, resistant cultivars/varieties and grafting, cropping system, soil solarization, biofumigants, soil amendments, anaerobic soil disinfestation, soil steam sterilization, soil fertility and plant nutrients, soilless culture and biological control methods may prove costly and inefficient when used alone. However, soil borne plant pathogens can be managed below the economic threshold level when these methods are applied as a system approach.

Introduction

The soil borne pathogens can be defined as pathogens that cause plant diseases via inoculum that comes to the plant by way of the soil. Vegetable crops are vulnerable to a range of pathogenic organisms that reduce yield by damaging whole plants or valued products and make them unmarketable. Plant diseases are responsible for as much as 26% of yield loss in global agriculture and sometimes there may be complete crop failure. Although the occurrence of plant diseases is a regular part of an ecosystem and crop production but it becomes a concern when disease takes form of epidemic causing havoc condition. Soil borne pathogens are particularly challenging because they survive in soil for many years, effecting crops for many years and are difficult to manage. Multiple soil borne pathogens sometimes result in a complex disease that can further damage the crop. Factors influencing how often and how seriously soil borne pathogen will affect plant health can be explained with the help of diagram represented below.

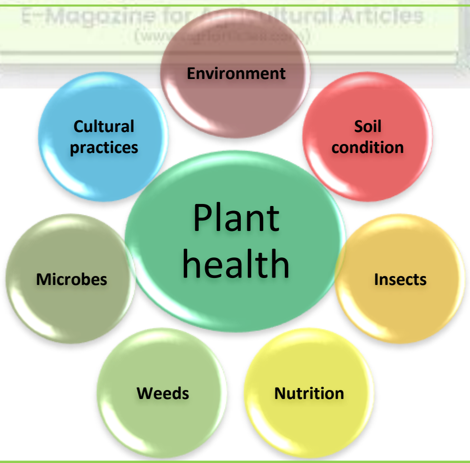

Figure 1. Factors contributing to plant health and resilience to soil-borne diseases.

Major Pathogen Group

Some of the most important soil-borne diseases are caused by pathogens that are 'soil inhabitants', have broad host ranges that include weeds, and produce long-lived survival structures. Important soil-borne pathogens include fungi, fungi-like organisms, bacteria as well as viruses and plant parasitic nematodes.

- Fungi cause most of soil borne vegetable diseases and so are considered the most important pathogen group.

Oomycetes: Aphanomyces, Bremia, Phytophthora, and Pythium.

Ascomycetes: Monosporascus and Sclerotinia.

Fungi Imperfecti: *Fusarium*, *Rhizoctonia*, and *Verticillium*.

Plasmodiophoromycetes: *Plasmodiophora brassicae* (causal agent of clubroot disease of brassicas) and *Spongospora subterranea* (causal agent of powdery scab of potato)

- Fewer diseases are caused by soil borne bacterial pathogens than by fungal pathogens. Examples of such bacteria are *Erwinia*, *Ralstonia* and *Streptomyces*. Pathogens in the *Pseudomonas* and *Xanthomonas* groups usually persist in the soil for only a short time.
- There are few soil borne viruses that affect vegetable crops. Soil borne viruses generally survive only in the living tissues of the host plant or in the nematode or fungal vectors that transmit them to the plant hosts. E.g. Beet soil borne furovirus, Lettuce big vein disease, Lettuce necrotic stunt disease.
- Nematodes are tiny, non-segmented roundworms. Soil borne plant-parasitic nematodes spend most of their lives in the soil, either as external feeders on plant roots or as residents inside roots. Root knot nematodes (*Meloidogyne* spp.) Cyst nematodes (*Heterodera* spp.) Needle nematodes (*Longidorus africanus*) Stubby root nematodes (*Paratrichodorus* spp.) are some important nematodes.

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). Few bacterial pathogens are true, long-term soil inhabitants; most survive for limited periods as saprobes on plant debris or roots, or directly in the soil. Some species survive by secreting slimy material that dries to form protective layers around the cells, enabling them to withstand unfavorable conditions. Fungal pathogens survive in soil as saprobes on host plant debris or on other types of organic matter present in soil, or as free-living organisms living directly in the soil. Many of these fungi produce resilient survival structures such as sclerotia, chlamydospore, oospore, etc.

Distribution: 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.

Ecology: Because soil ecology is so complex, it is also important that we define the ecological roles of soil borne pathogens. Soil borne pathogens can generally be divided into

- Soil inhabitants (those able to survive in soil for a relatively long time)
- Soil invaders or soil transients (those only able to survive in soil for a relatively short time).

Many Soil borne plant pathogens also can function and live as non-pathogenic soil organisms under certain conditions. If these pathogens are in contact with dead and decaying plant tissues, they can grow and survive on these substrates and thus be seen as saprobes or saprophytes (organisms that live on decaying plant organic matter).

Important Soil Borne Diseases in Vegetables

Crop	Disease	Pathogen	Symptoms and sign
Chilli	Bacterial wilt	*Ralstonia solanacearum*	Yellowing and stunting of plant. Browning of vascular tissue
	Damping off	*Phytophthora* spp. *Pythium* spp. *Rhizoctonia solani*	Poor stands wilting and death of emerged seedlings, discolored rotted roots and crown
	Phytophthora root rot	*Phytophthora capsici*	Aboveground stunting, wilting and death. Darkened rotted roots.
	Wilt	*Verticillium dahliae*	Aboveground stunting, wilting and death.
Potato	Charcoal rot	*Macrophomina phaseolina*	Stem lesions that result in aboveground wilting and yellowing.
	Fusarium dry rot	*Fusarium sambucinum*	Extensive dry, brown internal decay of tuber
	Powdery scab	*Spongospora subteranna*	Purple-brown color pustules that darken with masses of dark brown spore balls.
	Black scurf	*Rhizoctonia solani*	Red-brown stem lesions, yellowing of foliage if lesions griddle the stem. Leaf rolling in the aerial plant portion.
	Black leg	*Erwinia carotovora*	Inky black decay of stem, soft rot of tuber.
Tomato	Damping off	*Phytophthora* spp. *Pythium* spp. *Rhizoctonia solani*	Poor stands wilting and death of emerged seedlings, discolored rotted roots and crown
	White mould	*Sclerotinia sclerotiorum*	Soft, watery rot on the stems, profuse white mycelium and black sclerotia on bleached areas on affected stems.
	Bushy stunt	*Tomato bushy stunt virus*	Stunted and bushy plant, deformed fruits.
Cucurbitaceae	Charcoal rot	*Macrophomina phaseolina*	Water soaked green stem lesions that later turn tan. Profuse gumming on stems. Small, black structures (pycnidia) in lesions

	Damping-off	*Pythium* spp. and *R. solani*	Water soaked lesions on roots and stems, Wilting and death
	Fusarium wilt	*Fusarium oxysporum* f.sp *melonis* (Musk melon). *Fusarium oxysporum* f.sp *niveum* (Water melon). *Fusarium oxysporum* f.sp *cucumerinum* (Cucumber). *Pythium aphanidermatum*	Dark brown lesions on one side of the stems. Brown discoloration of vascular tissues.
Leafy vegetables	Damping-off	*Fusarium oxysporum*, *Pythium spp.* and *Rhizoctonia solani*	Poor stands, wilting and death of emerged seedlings. Discolored, rotted roots and crowns.
	Black rot	*Xanthomonas campestris* p.v *campestris*	Black veins, necrosis progress at edge of leaf in v- shape
Cole crops	Bottom rot	*Rhizoctonia solani*	Dark, discoloured leaves touching the soil. It occurs only on the brassicas which are forming the head.
	Club root	*Plasmodiophora brassicae*	Aboveground parts are stunting, roots are severely get swollen and blocks the transportation of water and minerals from roots to upper portion of the plants.
	Fusarium Yellows	*Fusarium oxysporum* f.sp. *conglutinans*	Above ground parts are stunting, wilting and death. Brown vascular discoloration. Primarily, occurs on cabbage.
	Wire stem	*Rhizoctonia solani*	Stunting, wilting and death of transplants. Hypocotyls are discolored, decayed and rotted. Brown mycelium present on decayed areas.
Onion & Garlic	Damping-off	*Pythium spp. Rhizoctonia spp.*	Poor stands, wilting and death and death of emerged seedlings. Discoloured rotted roots and crowns.
	Basal rot	*Fusarium oxysporum* f.sp. *cepae*	Chlorosis and dieback of foliage. Brown discoloration.
	Pink root	*Phoma terrestris*	Roots are turn pink, then purple. Roots wither and eventually die. Bulbs are stunted.
	White rot	*Sclerotium cepivorum*	Yellowing and eventual death of foliage. Decayed roots, stunted and dead plants, white mycelium and black sclerotia on infected bulbs.

Club root of clore crops

White rot of garlic


Black leg of potato


Damping off of seedlings


Brown rot of potato


Black rot of cole crops


Basal rot of onion


Charcoal rot

(**all images are adopted from internet)

Management of Soil Borne Diseases

1.) Host resistance: Disease-resistant plants are an obvious and effective control measure because resistance to many pathogens can be both complete and long lasting. A plant can express resistance through the action of a single gene that confers resistance (to certain races of Fusarium wilt, for example) or through multiple genes that result in a broad resistance to many pathogens.

- Single-gene resistance, called **vertical resistance**, limits both the initial level of infection and the production of inoculum. This sort of resistance can be overcome, however, by new strains of the target pathogen.
- Multiple-gene resistance, called **horizontal resistance**, allows some disease to develop but limits it to a tolerable level. Use resistant cultivars whenever they are available.

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.

Other methods

- Resistance conferred through specific plant genes
- Transgenic plants transformed with genes coding for Anti-pathogen compounds

2.) Cultural controls.

There are three areas of focus for cultural control:

- Helping plants avoid contact with pathogens,
- Reducing inoculum in the host plant's environment
- Creating environmental conditions that are unfavourable to disease development.

Cultural controls that reduce host-pathogen contact includes

- The use of fields that have no history of the soil borne disease of concern
- The inhibition of pathogen spread from infested soil to uninfected fields
- The use of seeds that do not harbour pathogens above acceptable established thresholds or the use of disease-free seeds and transplants
- The planting of seeds and transplants to proper depths.

Cultural methods that reduce inoculum levels in the environment include:

- **Crop rotation**
- 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.
- **Proper irrigation and providing good soil drainage**
- 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.
- Good soil drainage reduces the number and activity of certain oomycetes pathogens (e.g., *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*.
- **Good sanitation**
- Sanitation includes any sort of activities which are aimed to prevent the spread of pathogens by removing diseased and infected plant parts, decontamination of tools and equipment and washing hands. Weeds and volunteer plants should be destroyed as they can function as a host for pathogens as well as increase the relative humidity around the crop canopy, creating an environment in which many pathogens thrive.
- **Soil solarisation**
- When clear polyethylene is placed over moist soil during sunny summer days, the temperature at the top 5 centimeters 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.
- Certain **cover crops** (mustard species) and brassica crops (such as broccoli) can also help reduce soil borne pathogen populations; when incorporated into the soil, residues from these plants release chemicals that either directly inhibit pathogens or enhance soil microflora populations that subsequently compete with pathogens.

To create conditions unfavorable for disease development

- Use optimum plant spacing to reduce relative humidity around plants
- Use mulches to physically isolate aboveground plant parts from contact with the soil
- Fertilize the crop properly to prevent stressed or overly succulent plants.

3.) Biological control

Some important biological control agents with their mode of action and target soil borne pathogens are:

Biocontrol Agents	Target Pathogen	Mode of Action
Bacillus spp. (B. subtilis, B. amyloliquefaciens, B. firmus and B. pumilus)	*Pythium* spp., *Fusarium* spp., *Rhizoctonia solani, Aspergillus flavus*	Competition, direct antibiosis, induced resistance
Gliocladium catenulatum	Species of *Rhizoctonia, Pythium, Phytophthora, Fusarium, Didymella, Botrytis, Verticillium, Alternaria, Cladosporium, Helminthosporium, Penicillium* and *Plicaria*	Toxin production
Purpureocillium lilacinum* QLP 12 (previously *Paecilomyces lilacinus)	*Verticillium dahliae, R. solani* and nematodes	Parasitism
Trichoderma spp. (T. atroviride, T. asperellum, T. harzianum, T. viridae, T. gamsii* and *T. polysporum)	Species of *Rhizoctonia, Fusarium, Alternaria* and *Colletotrichum* as well as oomycetes, such as *Pythium* and *Phytophthora*	Competition, resistance and hyperparasitism
Pseudomonas spp.	*Pythium* spp. *R. solani*	Production of antibiotics, siderophores, volatiles

4.) Chemicals control

- Pre-plant fumigants (e.g., methyl bromide, chloropicrin, or metham sodium) are often highly successful in reducing soil borne inoculum, though their use is expensive and strictly regulated.
- Fungicide-treated seed is an important tool against certain seed and seedling diseases. In some situations, a fungicide applied to the soil or to plants can be an effective disease

management tool. For example, the application of fungicides to spinach seed lines at planting can effectively prevent damping-off caused by Pythium.

- 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. 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.
- For most soil borne pathogens, however, field-applied fungicides usually are not very effective.

Conclusions

Soil borne diseases are among the most destructive elements in vegetable crop production. Although the integrated soil borne disease management strategies may not eradicate all the pathogenic organisms from the soil, it entails continuous exploration and research for sustainable crop production which will secure a sustainable future for an ever-growing population.