

Invisible Invaders: How Soil Fungal Pathogens Threaten Our Food

Deepu Kumar^{1*}, Rishabh Kumar², Tannu Sri² and Subham Raj³

¹Ph.D. Scholar, Department of Plant Pathology, ²Ph.D. Scholar, Department of Horticulture (Vegetable Science), ³M.Sc., Department of Soil Science and Agricultural Chemistry, Bihar Agricultural University, Sabour, Bihar

Corresponding Author

Deepu Kumar

Email: deepukumardl9752@gmail.com



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ABSTRACT

Soil is living, with a rich ecosystem of microbes, insects and fungi that can help grow food. Many of these web-building microorganisms are beneficial but what makes soilborne fungal pathogens such a significant agricultural problem is that they infect plants, leading to plant diseases including rotting and wilting as well damping-off. These fungi debilitate the roots of plants and diminish their vitality by having spores, waiting to initiate under appropriate conditions. These pathogens not only cause losses of crops and quality produce but also create health hazards for farmers by producing allergens and mycotoxins. The soil borne fungi have an ability to survive in the soil and make difficult challenge to manage them vital for sustainable agriculture and food security.

INTRODUCTION

Soil is not simply dirt; it's a living ecosystem. There's a whole world of microbes, insects and fungi beneath our feet many of which support the growth of plants. Not all soil life's are beneficial. Soil borne fungal pathogens are among the most notorious villains that attack crops, gardens

and natural ecosystems. These fungi are sometimes unnoticeable.

Some soil fungi are pathogens of plants. Moreover, these are less damaging than the other two types (airborne and waterborne). Soil borne fungi that infect plant parts like

roots, often cause plant disease. These pathogens disrupt the root systems of plants, resulting in reduced nutrient uptake and overall plant vigour (Du *et al.*, 2022). These fungi can lie dormant and turn aggressive once the conditions are favourable. Soil borne fungal pathogens affect crops as well as farmers. Health issues like allergies and respiratory diseases in farmers can be caused by airborne spores and mycotoxins produced by these fungi. They inflict diseases like root rot and damping-off. Such serious diseases can severely reduce crop quality and yield. They damage the health of the farm as well as the consumer.

- The bacterium *Sclerotinia sclerotiorum* can cause a very high yield losses especially in cauliflower, broccoli, beans and potato crops. Plants wilting, stem rotting and sclerotia formation on infected plant parts.
- *Rhizoctonia solani* is a pathogen that infects a number of crops such as alfalfa and causes diseases like seedling damping-off and root rot which results in 20%-60% yield loss every year worldwide. It survives in the soil and in host plants through sclerotia. Thus, it is not very easy to control the fungus.
- *Fusarium* species- *Fusarium* species, which are notoriously persistent, inflict substantial damage to various crops, including potatoes and wheat. Mycotoxins they produce. The ecology of medusa and its management are complex.
- *Verticillium dahliae* causes vascular wilt diseases and is difficult to control due to its survival structures and resistances to chemical degradation. Scientists are looking for biological ways to solve problems.
- *Pythium* is harmful to seedlings as it will stunt growth and kill plants.

- *Aspergillus* species are mycotoxin producing fungi that can cause food safety and public health issues Ecological factors and climate change influence their pathogenicity.

Why Are They So Dangerous?

Fungi are capable of tolerating the climatic as well as environmental extremes thus they are able to survive under these variations. The spores can hibernate in the soil for a lot of years before getting activated when the right host plant appears. As soon as a plant get infected, the fungus multiply into vascular system of the plant which hinders water and nutrient flow. But it does not end here (Xia *et al.*, 2024). These germs spread one plant to another through soil, water and equipment so that farmers and gardeners face challenges.

Symptoms of Plant Diseases Caused by Soil borne Fungal Pathogens

- Root Rot. Brown or black mushy roots. The roots look rotten, and they smell bad. A stunted plant's growth is caused by damaged roots that cannot absorb water or nutrients. In the presence of mycelium, sporangia, or any of the fungal structures around roots in severe cases.
- Damping-Off: Seedlings collapse at the base or fail to emerge. Water-soaked lesions on stems, especially at soil level. A cottony fungal growth on or near the affected areas in humid conditions.
- Wilt Diseases: Leaves turn yellow, wilt, and eventually dry up. Browning or black streaks seen inside the vascular tissues of the stems. Plants generally die, despite having enough water, much early before dying. In some instances, the fungal spores can be observed on the stem surface.
- Crown and Collar Rot: The base of the plant at the soil line generally rots or

girdles. The tops collapsed, the base is getting weak. Fungal-like structures or discolored areas can be observed at the crown area.

- **Yellowing and Poor Growth:** Usually, the leaves bear the yellow tint uniformly, while it's common among the lower foliage. Plants are poorly vigorous, despite the fact that their care is entirely normal.
- **Leaf Spot and Blight (secondary symptomatology):** Irregular spots might develop on the leaves and turn brown and dry. Entire branches, sometimes sections of the plant, may die back.

Factors Contributing to the Development of Soil borne Fungal Pathogen Diseases

The development of Soil borne fungal pathogen diseases is influenced by various interrelated factors, including

1. Soil drainage and moisture

Poor drainage: Waterlogged conditions set stress at roots and this contributes toward making roots susceptible to infection through decreased soil oxygen.

Excess Moisture: Saturated soil contains an excess amount of moisture and can infect the plant roots with diseases like *Pythium* and *Phytophthora*.

2. Soil temperature

High-temperature favor multiplication of pathogens like *Fusarium* and *Rhizoctonia*.

Cold temperatures - Increase the activity of some pathogens such as *Verticillium*.

3. Soil pH

Many soil fungi are restricted to narrow pH ranges; for instance. Fusion prefers soil with a slight acid to nearly neutral pH. Example

Plasmodiophora brassicae (clubroot): More active in acidic soil. By manipulating the soil pH, the activity of the pathogen can either be minimized or entirely stopped (Shen *et al.*, 2022).

4. Host plant susceptibility.

Monocropping: Growing one crop continually into the same area enhances pathogen establishment, and in addition, increases the probability of severe disease build-up.

Susceptible varieties: Grown under a universal variety with little or no genetic resistance, which renders them more susceptible to infection.

5. Pathogen survival structures

Many soilborne fungi produce survival structures, such as sclerotia, fruiting bodies or spores, that are able to live many years without a host in the soil. *Sclerotinia sclerotiorum*, for example, produces long-lasting sclerotia; *Fusarium* spp. produces chlamydospores.

6. Irrigation Practices and overwatering

With flood irrigation, mycelium and fungal spores may spread throughout fields. Overwatering opts to maintain continually moist conditions conducive to fungal growth and infection.

7. Contaminated materials and tools

These pathogens may also enter into healthy soils via infected contaminated implements, seeds or planting materials. Soil movement from infected sites can disseminate these pathogens.

Managing Soil borne Fungal Pathogens

We can increase a crop's efficiency and competitiveness through different practices to ensure maximum resistance to diseases. Some effective practices in managing cultures are:

1. Crop rotation is a method of controlling diseases caused by pathogens. It involves growing host crops along with non-host crops in a planned sequence or arrangement to disrupt the life cycle of the pathogen. For eg.

- Change potatoes with cereals to reduce *Verticillium* wilt.
- Try to grow legumes in-between brassicas to suppress clubroot disease.

2. Soil Solarization is covering the soil with transparent plastic in a hot season. This plastic traps vapor and heat in the soil. This heat will kill all the pathogens in the soil of the upper layer. Works well against pathogens like *Fusarium*, *Rhizoctonia* and *Pythium*.

3. Water Management

- Too moist soil may result in root-rot and damping-off due to fungi like *Phytophthora*, *Pythium*, etc.
- Make sure fields have good drainage to avoid flooding.
- Watering your crops in the early morning allows the surface to dry before evening and minimizes humidity around the roots.
- 4. Prepare the soil properly it should be loose enough to breath so that roots can go deep.
- Improve soil structure and microbial activity by adding compost, farm yard manure or green manure.
- Control the pH level of the soil to a level that is unfriendly to a pathogen. We can use lime to manage clubroot in acidic soils.

5. Refrain from planting the same crop over a long period (Monocropping).

6. Encourage Beneficial Microbial Activity

- How It Works: Maintain a healthy soil microbiome by adding organic amendments and minimizing harmful inputs like excessive fungicides.
- Benefit: Beneficial microbes compete with pathogens, suppressing their growth (Nassary, 2025).

Biological Practices for Managing Soil borne Fungal Pathogens

Biological strategies in the control of Soil borne fungal pathogens involve microorganisms that help plants to combat these pathogens. These sustainable techniques help soil health and lessen the use of chemical controls. Here are those essential biological practices.

1. *Trichoderma* species are one of the most important pathogenic fungi that use biocontrol agents. It acts by colonising the roots of the plant. Further, it produces some fungal enzymes (Malik *et al.*, 2024). The enzymes produced breakdown the cell walls of pathogenic fungi like *Fusarium* and *Rhizoctonia*.

Can be used as seed treatments, soil amendments or as a spray?

- *Bacillus* Species- Bacteria like *Bacillus subtilis* produce antibiotics and enzymes that inhibit fungal pathogens.

Application: Used for soil inoculants or root dips

- *Pseudomonas fluorescens* bacteria produces secondary metabolites described as 'antibiotics' that suppress the pathogen *Pythium* and *Phytophthora*.

Application: Used as a soil or foliar spray.

2. Harmful Microbes: Mechanism of Action: These microbes directly compete with pathogens through processes like parasitism and antibiosis. Examples.

- *Streptomyces* species prevent *Verticillium* and different pathogens.
- *Coniothyrium minitans* targets *Sclerotinia* species sclerotia.

CONCLUSION

Control of soilborne fungal pathogens is dependent on a combination of practices that disrupt disease cycles, promote resistance in plants and stimulate beneficial organisms in the soil. Cultural practices, such as crop rotation, soil solarization, water management and biocontrol agents (*Trichoderma* and *Bacillus*), are used to safeguard crops naturally and sustainably. Farmers and gardeners, by learning to recognize and manage the environmental and biological factors that promote these pathogens, can create an environment for resilient crops in healthier agro-ecosystem needing fewer chemical controls.

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