

Soil-Borne Diseases Under a Changing Climate: Challenges and Solutions

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INTRODUCTION

Climate change has become one of the most pressing challenges for global agriculture. Increasing temperatures, irregular rainfall, prolonged droughts, floods, and shifting weather patterns are affecting crop growth and productivity across the world. These environmental changes not only influence plant growth but also alter the survival, distribution, and virulence of plant pathogens. Among these, soil borne diseases are of particular concern because they attack the underground parts of plants, often causing severe damage before visible symptoms appear. As climate variability intensifies, the frequency and severity of these diseases are expected to increase, posing a significant threat to sustainable crop production and food security. Soil borne diseases are caused by fungi, bacteria, oomycetes, nematodes, and other microorganisms that survive in the soil and infect plant roots, collars, stems, tubers, and bulbs. Pathogens such as *Fusarium spp.*, *Rhizoctonia solani*, *Pythium spp.*, *Sclerotium rolfsii*, *Macrophomina phaseolina*, and root-knot nematodes (*Meloidogyne spp.*) are responsible for substantial economic losses in cereals, pulses, oilseeds, vegetables, and horticultural crops. Many of these pathogens can survive in the soil for several years through resistant spores or sclerotia, making their management particularly difficult.

How Climate Change Influences Soil-Borne Diseases

Climate change affects the complex interaction between the pathogen, host plant, and environment, often referred to as the disease triangle. Even small changes in environmental conditions can significantly influence disease development.

Rising Temperature

Increasing temperatures accelerate the growth and reproduction of many soil-borne pathogens. Warmer soils encourage rapid pathogen multiplication and may increase the number of disease cycles within a cropping season. High temperatures also weaken plant defense mechanisms, making crops more susceptible to infection. Heat stress particularly favors pathogens such as *Macrophomina phaseolina*, which causes charcoal rot in soybean, maize, sesame, and pulses.

Irregular Rainfall and Waterlogging

Extreme rainfall events have become more common due to climate change. Excessive soil moisture reduces oxygen availability around plant roots, creating favorable conditions for pathogens such as *Pythium* and *Phytophthora*. Waterlogged fields promote damping-off, root rot, and seedling blight, resulting in poor crop establishment and yield losses. Floodwater may also spread pathogens from infected fields to healthy areas.

Drought Stress

Long periods of drought weaken plants by reducing water and nutrient uptake. Drought-stressed crops become more vulnerable to soil-borne pathogens, especially those adapted to dry conditions. In addition, cracks formed in dry soils facilitate the entry of pathogens into plant roots.

Mild Winters

Traditionally, low winter temperatures suppress many soil-borne pathogens. However, warmer winters allow these pathogens to survive and remain active throughout the year. As a result, disease outbreaks may occur earlier in the cropping season and persist for longer periods.

Changes in Soil Microbial Communities

Climate change alters soil microbial diversity and biological activity. Beneficial microorganisms that naturally suppress pathogens may decline under stressful environmental conditions, allowing disease-causing organisms to dominate. Maintaining a balanced soil microbiome is therefore essential for sustainable disease management.

Major Soil-Borne Diseases Affecting Crops

Several important diseases threaten agricultural production under changing climatic conditions.

- **Fusarium wilt:** Causes yellowing, wilting, and vascular discoloration in tomato, chickpea, banana, cotton, and many vegetable crops.
- **Rhizoctonia root rot:** Responsible for damping-off, stem canker, and root rot in cereals, vegetables, and legumes.
- **Pythium damping-off:** Attacks seeds and young seedlings, particularly under wet soil conditions.
- **Sclerotium collar rot:** Produces white fungal growth and brown sclerotia near the stem base, leading to plant death.
- **Charcoal rot:** Favored by hot and dry conditions, resulting in significant yield losses in pulses and oilseed crops.
- **Root-knot nematodes:** Produce root galls that interfere with water and nutrient uptake and increase susceptibility to secondary infections.

Symptoms and Economic Importance

Common symptoms of soil-borne diseases include:

- Poor seed germination
- Seedling mortality
- Yellowing and wilting of leaves
- Root and collar rot
- Stunted plant growth
- Reduced tillering
- Premature drying of plants
- Sudden plant death

These diseases reduce crop yield, quality, and profitability. Depending on the crop and environmental conditions, yield losses may vary from **10% to more than 70%**. Farmers also incur additional costs for fungicides, soil treatments, and replanting.

Integrated Management Strategies

Successful management of soil-borne diseases requires an **Integrated Disease Management (IDM)** approach rather than relying solely on chemical pesticides.

1. Crop Rotation

Rotating susceptible crops with non-host crops interrupts the life cycle of soil-borne

pathogens and gradually reduces their population. A rotation period of two to three years is recommended for heavily infested fields.

2. Disease-Free Seed and Resistant Varieties

Using certified disease-free seed minimizes the introduction of pathogens into the field. Resistant or tolerant varieties provide long-term protection and reduce dependence on fungicides.

3. Balanced Soil Fertility

Healthy plants are naturally more resistant to diseases. Farmers should apply fertilizers based on soil-test recommendations and incorporate organic manures, compost, and biofertilizers to improve soil fertility and microbial activity.

4. Biological Control

Beneficial microorganisms such as *Trichoderma harzianum*, *Trichoderma viride*, *Pseudomonas fluorescens*, and *Bacillus subtilis* effectively suppress many soil-borne pathogens through competition, antibiosis, and induced systemic resistance. Seed treatment and soil application of these bioagents provide environmentally friendly disease management.

5. Soil Solarization

Covering moist soil with transparent polyethylene sheets during the hot summer months for 4–6 weeks raises soil temperature sufficiently to destroy many harmful fungi, nematodes, and weed seeds. Soil solarization is particularly useful in vegetable nurseries.

6. Proper Irrigation and Drainage

Efficient water management is essential. Farmers should avoid over-irrigation and ensure proper drainage to prevent waterlogging. Drip irrigation is preferable because it supplies water directly to the root zone while reducing excess soil moisture.

7. Field Sanitation

Removing infected crop residues, diseased plants, and volunteer hosts helps reduce pathogen inoculum. Farm tools should also be cleaned to prevent the spread of pathogens between fields.

8. Judicious Use of Fungicides

Where disease pressure is high, recommended fungicides should be used according to

agricultural guidelines. Fungicides should always be integrated with cultural and biological methods to delay resistance development and minimize environmental impacts.

Climate-Smart Solutions for Farmers

To reduce the impact of climate change on soil-borne diseases, farmers should adopt climate-smart agricultural practices, including:

- Conservation agriculture and minimum tillage
- Crop diversification
- Cover cropping and mulching
- Organic matter enrichment
- Precision irrigation
- Weather-based disease forecasting
- Regular soil testing
- Promotion of beneficial soil microorganisms

These practices not only reduce disease incidence but also improve soil health, water-use efficiency, and crop resilience.

CONCLUSION

Climate change is increasing the threat posed by soil-borne diseases to agricultural production worldwide. Rising temperatures, erratic rainfall, drought, and waterlogging create favorable conditions for pathogens while weakening plant resistance. Because soil-borne pathogens survive for long periods in the soil, their management requires a holistic and integrated approach rather than dependence on chemical pesticides alone. Improving soil health through organic matter addition, crop rotation, resistant varieties, biological control, balanced nutrition, efficient irrigation, and proper field sanitation forms the foundation of sustainable disease management. By adopting climate-smart agricultural practices and integrated disease management strategies, farmers can reduce disease losses, enhance crop productivity, and protect the long-term health of their soils. Healthy soils are the key to healthy crops, resilient farming systems, and sustainable food security in a changing climate.