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Rooted in Health: Strategies to Control Soil-Borne Diseases

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Soil-borne diseases are caused by plant pathogens that survive in the soil and crop residues. These pathogens infect plant roots, crowns, and other underground tissues, affecting plant growth and productivity. The soil acts as a reservoir of inoculum, allowing pathogens to survive for extended periods and infect susceptible crops under favourable conditions. The symptoms of soil-borne diseases often remain hidden until the infection becomes severe. Common symptoms include stunting, wilting, chlorosis, root rot, reduced growth, and plant death. These diseases are difficult to manage because pathogens may survive in the absence of their usual hosts, infect a wide range of plants, and persist in soil for several years. Chemical control is not always effective or economical, and developing resistant crop varieties can be challenging. Therefore, an integrated disease management approach is essential to reduce disease incidence and minimize crop losses.

Management of Soil-Borne Diseases

Soil-borne diseases can be managed through an integrated approach involving preventive, cultural, physical, biological, and chemical methods. The use of resistant or tolerant varieties, proper field sanitation, balanced fertilization, good drainage, and effective irrigation management helps reduce pathogen survival and spread.

Preventive Measures

Prevention is one of the most important strategies for managing soil-borne diseases. The introduction and spread of pathogens can be minimized through the following practices:

- Use quality seeds and certified disease-free planting material.
- Select well-drained nursery sites with adequate sunlight.
- Avoid using poorly drained fields for nursery production.
- Restrict machinery movement in infested areas, particularly when the soil is wet.
- Prevent the movement of contaminated soil from infested to healthy areas.
- Avoid excessive irrigation, waterlogging, and surface runoff.
- Do not move infected plants between nurseries or fields.
- Select resistant cultivars and plant crops at the appropriate time.
- Avoid injuries to roots and other plant tissues.
- Avoid excessive fertilizer application, which may interfere with proper root development.

Managing soil pH can also help suppress certain diseases. For example, raising soil pH to approximately 6.5–7 using suitable nutrient management practices, including nitrate nitrogen instead of ammoniacal nitrogen, may reduce Fusarium wilt development.

Cultural Control

Cultural control involves agricultural practices that reduce pathogen survival, multiplication, and spread.

Crop rotation: Growing non-host crops for three to four years can reduce pathogens that depend on specific crop hosts. Crop rotation is more effective against pathogens that survive mainly on living plants or crop residues. However, it is less effective against pathogens that

produce long-lived survival structures or persist in soil for many years. Fallow periods may also reduce pathogen populations through decomposition, drying, and exposure to high temperatures.

Tillage practices: Soil cultivation and deep ploughing help bury infected crop residues and expose pathogens in the upper soil layers to drying. Sub-soiling can reduce soil compaction and improve crop performance. Combining suitable tillage practices with tolerant cultivars may help reduce root rot and other soil-borne diseases.

Soil amendments: Organic amendments such as sawdust, straw, oil cakes, castor cake, and neem leaves can help suppress certain soil-borne pathogens. They may promote beneficial microorganisms and improve soil conditions. Lime and sulphur can also be used to adjust soil pH where appropriate. The source material gives examples of lime application for clubroot of cabbage and sulphur application for common scab of potato.

Plant density: Plant spacing influences humidity, air circulation, and disease spread. Close spacing increases humidity and may favour sporulation by pathogenic fungi. Wider spacing and appropriate plant populations can reduce disease severity in susceptible crops. High planting density may increase damping-off in chilli nurseries and crown rot in wheat.

Fertilizer management: Balanced fertilizer application improves plant health and can influence disease severity. Phosphatic fertilizers may support host resistance by increasing phytoalexin production. Ammonium bicarbonate has been reported to reduce the viability of *Sclerotium rolfsii* sclerotia, while gypsum may reduce Macrophomina-associated disease incidence in groundnut.

Irrigation and drainage: Good drainage and appropriate irrigation management reduce waterlogging and limit the movement of water-dispersed pathogens. Excess moisture can favour organisms such as Pythium. In some situations, prolonged flooding or dry fallowing may reduce selected pathogens and nematodes. Removing infected plants promptly can prevent further inoculum buildup.

Weed control: Weeds may act as alternate hosts or provide organic material that supports pathogen survival. They can also alter the crop microclimate and influence soil microorganisms. Effective weed management helps reduce pathogen reservoirs and disease development.

Physical Control

Soil Solarization: Soil solarization is a physical method of disease management in which moist soil is covered with transparent polyethylene sheets during hot, sunny weather. Solar heat raises soil temperature and reduces populations of soil-borne fungi, bacteria, and nematodes, particularly near the soil surface.

Under favourable conditions, temperatures in the upper five centimetres of covered soil may reach approximately 52°C, compared with about 37°C in uncovered soil. Maintaining these conditions for several days or weeks can reduce pathogen inoculum. Soil solarization can help manage Fusarium wilt, Verticillium wilt, and bacterial canker of tomato. Sublethal heating may also make surviving pathogen structures more susceptible to biological control agents.

Cover Crops: Cover crops, particularly mustard and other Brassica species, can contribute to soil-borne disease management. Their incorporation into soil may suppress certain pathogens, improve soil microbial activity, and create unfavourable conditions for disease development.

Brassica plants contain glucosinolates, which can release biologically active compounds such as allyl isothiocyanate. These compounds may contribute to the suppression of pathogens such as *Rhizoctonia solani* and *Gaeumannomyces graminis* var. *tritici*. The effectiveness of cover crops depends on the species used, their chemical composition, and their interaction with soil microorganisms.

Biological Control

Biological control involves using beneficial organisms to suppress plant pathogens. In natural and agricultural soils, some microorganisms inhibit pathogens through competition, antibiotic production, parasitism, or other antagonistic activities.

Beneficial microorganisms such as *Trichoderma*, *Pseudomonas, Bacillus*, *Penicillium*, and *Streptomyces* can contribute to the suppression of soil-borne diseases.

Mechanisms of Biological Control

Antibiosis: Beneficial microorganisms produce antibiotics or other substances that inhibit pathogen growth. For example, zwittermicin A produced by Bacillus cereus has been associated with the suppression of Phytophthora root rot in alfalfa.

Nutrient competition: Beneficial microorganisms compete with pathogens for essential resources such as carbon, nitrogen, oxygen, and iron. This competition reduces the availability of nutrients required for pathogen growth and multiplication.

Mycoparasitism: Certain fungi parasitize other fungi directly. They may attach to pathogen structures, penetrate them, or produce cell-wall-degrading enzymes and inhibitory substances that suppress their growth.

Requirements for Successful Biocontrol

Successful biological control requires an effective strain that can survive, compete, colonize plant roots, and multiply under field conditions. The organism should be non-pathogenic to the host plant and safe for the environment. Production and formulation methods should be economical and capable of maintaining the organism's viability during storage. The biocontrol agent must also be applied in a way that allows it to establish and function effectively. *Trichoderma* species are widely distributed in agricultural soils and are used as biological control agents and plant growth promoters. Their antifungal activity is associated mainly with mycoparasitism and competition for nutrients.

Suppressive Soils

Suppressive soils are soils in which pathogens develop less readily and cause less severe disease than in conducive soils. This suppression is often associated with beneficial microorganisms that inhibit pathogen growth through antibiotics, lytic enzymes, nutrient competition, or direct parasitism. Fungi such as *Trichoderma*, *Penicillium*, and *Sporidesmium*, and bacteria belonging to Pseudomonas, Bacillus, and Streptomyces, have been associated with disease suppression. Adding suppressive soil to conducive soil may introduce antagonistic microorganisms and reduce disease development. For example, soil containing a *Streptomyces* strain antagonistic to the potato scab pathogen has been used to reduce potato scab. Suppressive soil has also been used to help manage Phytophthora root rot of papaya.

Mycorrhizal Fungi and Disease Suppression

Mycorrhizal fungi form beneficial associations with plant roots and can help protect plants against soil-borne pathogens.

They suppress disease through several mechanisms:

- Physical protection: Fungal structures around roots can act as a barrier against certain pathogens.
- Production of antagonistic substances: Mycorrhizal fungi may produce antibiotics and other compounds that inhibit harmful organisms.
- Competition: They compete with pathogens and improve nutrient uptake, particularly phosphorus, helping plants tolerate disease.
- Changes in root exudates: They can alter substances released by roots, making conditions less favourable for certain pathogens.

Studies described in the source material reported increased eggplant fruit numbers and fruit weight following inoculation with Gigaspora margarita, together with a lower incidence of Verticillium wilt. Mycorrhizal fungi have also been associated with improved root growth in plants exposed to Fusarium oxysporum.

Chemical Control

Chemical control involves using suitable pesticides and soil treatments to protect plants or reduce pathogen populations before infection occurs. Treatments may include soil fumigation, soil drenching, seed treatment, and the application of fungicides through irrigation systems where appropriate.

Soil treatments are often used in high-value crops to manage nematodes and selected soil-borne fungi, including Fusarium and Verticillium. Fungicides may help control damping-off, seedling blights, crown rot, and root rot. The source material mentions metalaxyl, propamocarb, prothiocarb, pentachloronitrobenzene (PCNB), captan, and chloroneb among chemicals used for particular soil or seed treatments. Fosetyl-Al is also mentioned for managing certain soil-borne pathogens through foliar application. Chemical treatments should be selected according to the crop, target pathogen, and locally approved product label. They should be integrated with cultural and biological methods rather than used as the sole management strategy.

Conclusion

Soil-borne diseases are a major constraint to crop health and productivity because their pathogens can persist in soil and infect plants over long periods. Effective management requires an integrated approach combining prevention, crop rotation, tillage, soil amendments, balanced fertilization, proper plant spacing, irrigation management, weed control, soil solarization, cover crops, biological control, and appropriate chemical treatments. The use of beneficial microorganisms, suppressive soils, mycorrhizal fungi, and resistant or tolerant varieties can further strengthen disease management. Combining these strategies helps reduce pathogen populations, protect plant roots, maintain soil health, and minimize crop losses.

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