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EFFECTIVE ORGANIC STRATEGIES FOR PLANT DISEASE MANAGEMENT

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INTRODUCTION

The evolution of agriculture, especially since World War II, has seen the advent of the "Green Revolution" with its widespread use of mechanization, fertilizers, and pesticides to meet the demands of a growing population. While this era brought increased food production, concerns arose over the environmental impact and sustainability due to unchecked chemical use. The health and vitality of plants are paramount for a successful harvest. Plant diseases can wreak havoc on crops, leading to significant economic losses and threatening global food security. Recognizing the importance of soil health, organic agriculture popularized in the early twentieth century. However, plant diseases remain a significant issue, posing economic threats to agriculture. While conventional methods often rely on synthetic chemicals, there is a growing interest in adopting organic strategies for plant disease management. This article explores effective organic approaches that promote sustainable farming practices and protect crops from diseases to reduce crop failure losses.

The Food and Agriculture Organization (FAO) suggests that organic agriculture is a *"unique production management system. This system promotes and enhances agroecosystem health, including biodiversity, biological cycles, and soil biological activity. The accomplishment of these goals is achieved by excluding all synthetic off-farm inputs and, instead, making use of on-farm agronomic, biological, and mechanical methods".*

DISEASE MANAGEMENT IN ORGANIC AGRICULTURE

In agriculture, disease incidence is reliant upon three conditions: the presence of a disease-causing pathogen, a susceptible host, and a conducive environment. Disease management strategies in organic farming primarily adopt preventive measures, aiming to create less favorable environments for diseases and reduce host susceptibility. Successful disease management requires a comprehensive understanding of crop and pathogen life cycles, as well as their interactions with soil, climate, and other production system factors. Organic agriculture depends on the concept that natural processes within an agro-ecosystem are interdependent. The management approach focuses on supporting and maintaining self-regulation through these natural processes.

Several methods are classified as physical, biological, genetic, and agronomic strategies (Fig. 1), which are all effective at altering the microenvironment to prevent pathogen activity. The objective is to stop infections from causing harm that is greater than what is economically feasible by adopting a range of tactics. These strategies emphasize the necessity for a variety of approaches in line with crop growth stages and the disease cycle and are customized to the specific disease impacting a certain crop. For the management of plant diseases in a particular agro-climatic zone to be effective, these strategies must be integrated into a cohesive module.

AGRONOMIC PRACTICES

Agronomic methods play a crucial role in managing plant diseases in organic agriculture. Key practices include:

1. Sanitation: Remove and destroy infected plants regularly to prevent disease spread. This includes pruning infected parts, treating plant material, burning infected crop stubble, and establishing barriers to prevent pathogen transmission.

2. Crop Residue Management: Decompose crop residues to enhance soil health and disease control. The rate of decomposition affects pathogens growth and survival. Practices like tillage and crop rotation can lower pathogen inoculum density, deprive pathogens of hosts, and promote conditions favoring beneficial microorganisms.

3. Tillage: Minimize soil disturbance through reduced tillage or zero tillage to sequester carbon in the soil, increase organic matter, and enhance microbial decomposition. Reduced tillage practices help control diseases by removing primary sources of inoculum.

4. Crop Rotation: Implementing a well-designed crop rotation is essential for disease management. Rotation disrupts the life cycles of soil-borne pathogens, reducing their activity, pathogenesis, and survival. However, its effectiveness depends on factors such as host range, pathogen survival mechanisms, inoculum levels, crop susceptibility, and soil conditions.

5. Soil Disinfestations: Soil disinfestations are crucial for reducing the initial inoculum in organic agriculture. In order to prepare soil for planting, it must be flooded with at least 30 cm of water for three to four months. Limitations include ineffectiveness with large pathogen populations and dependency on abundant water resources. Solarization of soil involves the exposure of moist soil to sunlight for several days while it is enclosed in a UV-resistant plastic sheet. It is efficient against a wide range of fungi, bacteria, and nematodes that can damage plants. Incorporating isothiocyanate-producing residues from brassica crops enhances the solarization effect. Benefits include improved plant growth, increased nutrient availability, and enhanced soil tilth. Successful in managing diseases caused by many fungal, bacterial, and nematode phytopathogens.

In anaerobic soil disinfestations, fresh decaying matter is mixed into the soil, which is then dampened and protected for three to six weeks with an airtight plastic cover. Bacteria that are multiplying consume oxygen, which causes anaerobic breakdown. Toxic compounds accumulate, affecting soil pH and pathogen survival. Controls various soil-borne pathogens and weeds, resulting in long-term disease suppression. On the contrary, Bio fumigation Involves adding organic amendments, often green manure crops like *Brassica* spp., releasing toxic compounds upon decomposition. Compounds like organic cyanides and ammonia gas exhibit fungistatic or biocidal properties, controlling a wide range of pathogens and nematodes.

6. Application of Organic Amendments: Improves soil health and suppresses diseases by enhancing microbial diversity. Composts, green manures, and animal manures increase soil biological activity. Neem cake, used as a soil amendment, contributes significantly to nematode and soil-borne pathogen control.

7. Cultural Control: Focuses on preventive practices to reduce inoculum and create unfavorable conditions for pathogen growth. Measures include choosing optimal planting dates, field sanitation, weed management, and proper drainage. Crop rotations, variety selection, and maintaining a diverse population of beneficial organisms contribute to disease prevention in organic farming.

8. Management of Environment: Weather fluctuations affect agricultural production, affecting crop yields, weed, pest, disease incidence, and economic costs. The evolving climate contributes to frequent disease outbreaks by breaking crop resistance and facilitating the acclimatization of pathogens. Adjusting the seeding date helps prevent destructive diseases by avoiding the coinciding of susceptible plant stages with optimal pathogen conditions. Delayed emergence and regulating sowing depth can mitigate infection risk. Optimal planting schedules can aid in the prevention of disease outbreaks, thereby contributing to the efficacy of disease management in organic agriculture.

The mixed cropping approach involves cultivating two different crops together in the same field, characterized by root interactions and crop root architecture. Host dilution is a critical mechanism for reducing diseases spread by soil in mixed cropping. The process consists of establishing root boundaries between diseased and healthy plants, increasing the distance between host plants, and releasing toxic root exudates. Disease suppression may be indirectly influenced by factors other than the pathogen, as the non-host crop functions as a physical barrier that restricts disease spread. The intensity of root intermingling and disease suppression levels depend on the crops, cultivars, and their root architectures. By preventing splashing spores and raindrops from penetrating, the non-host crop acts as a barrier to restrict the dispersal and extension of the disease.

9. Allelopathy: Allelopathy denotes the occurrence of both advantageous and detrimental biochemical reactions between plants, which are facilitated by microorganisms. For instance, intercropping watermelon with rice reduced *Fusarium oxysporum* f.sp. *melonis* wilt by 67%, as allelopathic substances from rice roots hindered germination in the rhizosphere. Allelopathic effects are localized, emphasizing the need for high concentrations in specific microsites for pathogen inhibition.

PHYSICAL TREATMENTS

Physical treatments refer to the application of various physical agents and techniques to control or eliminate seed-borne pathogens without causing harm to the host tissue. These methods leverage heat, steam, air, and other physical factors to inactivate or immobilize microorganisms and viruses while preserving the integrity of the seeds. Below are several physical treatments commonly employed:

1. Heat Therapy: Heat therapy involves the use of water, steam, air, or microwave radiation to control pathogens. The primary concept revolves around inactivating or immobilizing microorganisms and viruses at temperatures that do not harm the seeds. This method is often applied to a variety of hosts to enhance their resistance to diseases.

2. Hot Water Treatment: Hot water treatment is a stepwise process that includes seed selection, pre-soaking, pre-heating, hot water soak, cooling, and drying. It has proven effective against bacteria and viruses, providing an eco-friendly and economically viable approach. However, it is often limited to treating small quantities of seeds due to practical constraints.

3. Hot Air Treatment: This technique involves exposing seeds to hot air, making it less injurious than hot water treatment. It is relatively easy to operate but may be less effective. Hot air treatment finds application in combating diseases in crops such as sugarcane and tomatoes. For instance, drying tomato seeds within the temperature range of 29.5-37.5 °C has been shown to eliminate *Phytophthora infestans*.

4. Aerated Steam Treatment: Safer than hot water treatment and more effective than hot air treatment, aerated steam treatment is utilized in greenhouses and soil treatment. It has been shown to achieve complete eradication of pathogens even at lower temperatures, making it a versatile method for seed-borne pathogen control.

5. Moist Hot Air Therapy: Proposed for eliminating grassy shoot disease in sugarcane, moist hot air therapy involves exposing seeds to hot air, aerated steam, and moist hot air. This integrated approach aims to enhance efficacy and control specific diseases in crops like sugarcane.

6. Solar Heat Therapy: Solar heat therapy is a simple technique that utilizes natural solar heat for eliminating seed-borne pathogens. Seeds are soaked in cold water and then dried in the sun. Care is needed to avoid thermal injuries to the embryo during this process, making it a cost-effective and environmentally friendly approach.

DISEASE RESISTANT VARIETIES

Plant resistance to diseases and pests is a natural phenomenon shaped by the interaction between hosts and pathogens over time. Genetic methods in organic farming focus on utilizing natural resistance in plants through disease-resistant varieties and multiline approaches. While disease-resistant varieties target specific diseases, multiline strategies offer functional diversity and stability against a broader spectrum of diseases. Careful selection and breeding practices are essential for maintaining product quality in variety mixtures. Resistant varieties are a low-input alternative to chemical pesticides in organic agriculture, exploiting host genetic diversity. Disease-resistant varieties remain disease-free due to genetic traits such as leaf and stem toughness, maturity time, nutrient content, and plant architecture. This strategy is disease-specific and effective against a limited number of diseases, addressing gene-for-gene interactions between hosts and pathogens.

Multiline Varieties: Multiline varieties and variety mixtures provide functional diversity, limiting the expansion of pathogens and pests in cropping systems. These approaches reduce the risk of resistance breakdown. Multiline varieties and mixtures prevent the rapid evolution of complex pathotypes through barrier and frequency effects, inducing resistance and differential adaptation. Yield stability is higher in mixtures than in pure stands, offering an effective strategy against various diseases. Farmer and processor concerns about potential negative effects on product homogeneity may limit the wider application of variety mixtures. Careful selection and breeding progress can maintain or enhance product quality in mixtures, addressing concerns about homogeneity.

BIOCONTROL STRATEGIES

In organic agriculture, bioagents provide a cost-effective and useful way to manage plant diseases. Enhanced biological control through the utilization of natural antagonists and inundative biological control through the introduction of competitors, antagonists, predators, or parasites are two approaches to biological control. Various plant diseases can be effectively treated by *Trichoderma* spp, *Pseudomonas* spp, and *Bacillus* spp. Regarding fungal diseases, *Arthrobacter, Bacillus, Pseudomonas*, and *Serratia* have demonstrated effectiveness. Fungal pathogens such as *Phytophthora* spp. can be controlled by *Pseudomonas fluorescens*. *Bacillus* sp. inhibits soil-borne pathogens and speeds up plant growth. Bio-fungicides containing living organisms are offered in suspension, particulate, and powder forms. Numerous diseases can be efficiently controlled by treating seeds with *P. fluorescens* or *Trichoderma harzianum*.

Optimization of organic disease management is achieved through the incorporation of biocontrol agents alongside cultural methods, soil solarization, and disease-resistant varieties. Biocontrol agents provide a sustainable and ecologically beneficial method for organic agriculture by being compatible with a range of disease management techniques. Integrating with various techniques improves overall health care management. In nurseries growing tomatoes, brinjal, and capsicums, the combination of soil solarization with *T. harzianum* or *P. fluorescens* applied to the seeds or roots efficiently controls seed and seedling infections. The successful management of wilt and root-rot complexes in chickpea, lentil, and pigeon pea can be achieved through the integration of *T. harzianum* or *T. virens* with soil management practices. provide a cost-effective and useful way to manage plant diseases. Two strategies include enhanced biological control through natural enemies and inundative biological control via the release of specific competitors, antagonists, predators, or parasites. *Trichoderma* spp., *Pseudomonas* spp., and *Bacillus* spp. are effective against various plant diseases. Bacteria like *Bacillus, Pseudomonas, Serratia*, and *Arthrobacter* show efficacy against fungal diseases. *Pseudomonas fluorescens* controls fungal pathogens like *Phytophthora* spp. *Bacillus* sp. accelerates plant growth and suppresses soil-borne diseases. Bio-fungicides with living organisms are available in powder, granular, and suspension forms. Seed treatment with *Trichoderma harzianum* or *P. fluorescens* effectively controls many diseases. Integration of biocontrol agents with cultural practices, soil solarization, and disease-resistant varieties enhances organic disease management.

Biocontrol agents offer compatibility with various disease management strategies, providing an environmentally friendly and sustainable approach in organic agriculture. Integration with different practices enhances overall disease control. Combination of seed/root application of *T. harzianum* or *P. fluorescens* with soil solarization effectively manages seed and seedling diseases in tomato, brinjal, and capsicum nurseries. Integration of *T. harzianum* or *T. virens* with soil management practices successfully manages wilt and root-rot complexes in chickpea, lentil, and pigeon pea.

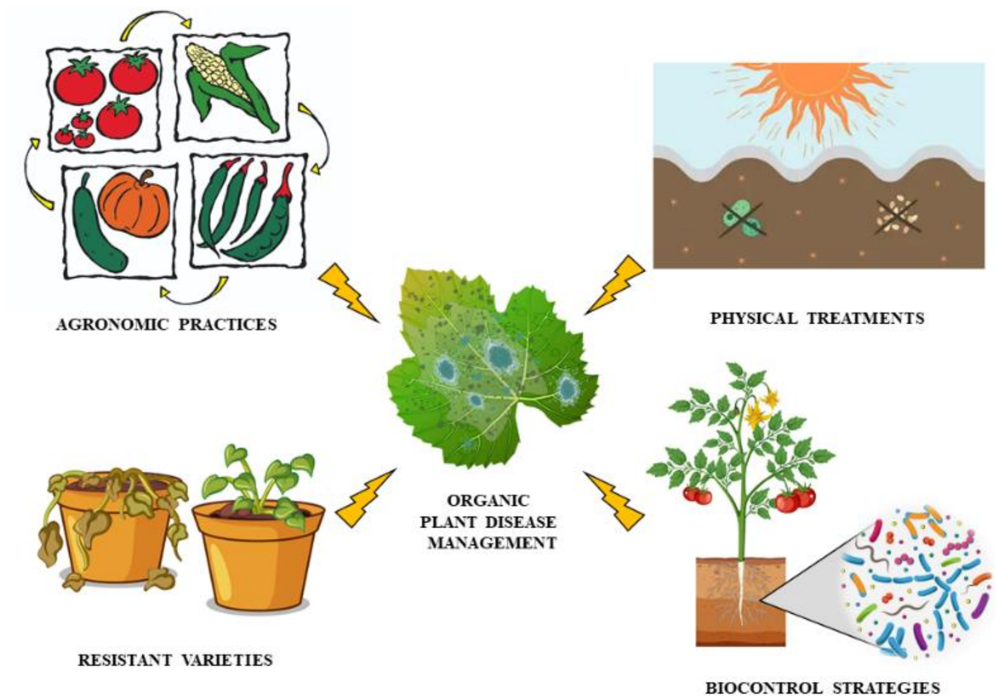

Figure. 1 Organic plant disease management strategies