DOI: https://doi.org/10.54083/978-81-980121-1-1-3

CHAPTER : 03

Integrated Disease Management: Concepts and Applications

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Abstract

One of the main biotic limitations that significantly reduce crop yields is plant disease. Pests and diseases have proliferated in a number of cropping systems as a result of the shifting cropping system pattern, which has altered the cropping situation making plants more vulnerable to plant diseases. The use of pesticides has been the main approach of disease control for the past few decades in both industrialised and increasingly developing nations. However, a number of issues have been linked to this strategy, including the detrimental effects of fungicides on the environment and human health as well as the frequent emergence of disease resistance in pathogens. Integrated disease management is the sole approach that offers acceptable yield and quality at the lowest possible cost and in an environmentally responsible manner integrating together all the components like host resistance, biological, cultural, physical and chemical strategies. Gaining traction at the national level requires a broad acceptance of IDM practices. Appropriate consideration of policies across various domains like land use, education and awareness, trade, export, food safety, crop protection and agricultural extension activities, must be considered for successful implementation of IDM.

Keywords Biological control, Cultural control, Integrated disease management, Plant disease

1. Introduction

Plant diseases are caused by intricate interactions between biotic and abiotic factors, such as hosts, pathogens and environments. Vectors as well as human activities also intentionally or unintentionally alter these interactions through agricultural practices like cropping systems, deployment of resistance genes and the use of pesticides (Burdon *et al.*, 2014). Agricultural

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In: Current Trends in the Diagnosis and Management of Plant Diseases. (Eds.) Dutta, P., Upamanya, G.K., Pandey, A.K., 2024. Biotica Publications, Tripura, India.

techniques used in plant disease management in recent decades have created ecological environments that facilitate evolution of pathogen resulting in more severe infection.

This exacerbates the detrimental effects of plant disease on food security and human environment. Modern agricultural systems are forced to transition to large-scale, intensive and specialised farming due to increasing food demand and superior quality of crops which has interrupted the co-evolutionary dynamics between pathogens and host plants, occurring naturally leading to an increase in the frequency and intensity of disease epidemics as well as the emergence of novel diseases. However, over the past 50-100 years, the adoption of different plant disease management strategies have failed to bring reforms in the risks and patterns of disease occurrence further increasing disease problems.

It is therefore crucial to apply a holistic thinking approach to comprehend the complete interaction between host and pathogen and their relationship with the surrounding environment in order to accomplish effective and sustainable plant disease control (Burdon and Thrall, 2008). Further, different mechanisms involved in host plant defences (genetic, biological and physiological), epidemics of the pathogen, studies on pathogens' interaction with microbial populations, habitat of the pathogen and knowledge of the pathogenesis are some of the important points to be considered. Studies on the emergence of new pathogen and its evolution, interactions among pathogens, plants, vectors and the environment, effect on plant development and health should be conducted by scientists and researchers to fully comprehend the effect of different human activities like pesticide use, international trade and agricultural practices (like monoculture and rotation) on them (He *et al.*, 2016).

This management method consists of two primary parts: dynamic and combined techniques directed by a thorough understanding of the gradual development of specific host-pathogen interactions along with their ecology and numerous goals (efficiency, high production, safety and good quality). In order to maximise the advantages of plant disease control from an ecological, social and economic standpoint, this holistic approach holds out great scopes for solving the issues and difficulties related to existing solutions (Xie *et al.*, 1983).

The term "integrated plant disease management" refers to a decision-making process that uses a coordinated approach combining several strategies to maximise pathogen control in an environmentally and financially responsible manner. IDM often entails scouting along with the prompt implementation of a number of methods and tactics. These could involve proper location selection, using resistant cultivars, changing planting techniques, adjusting the environment through irrigation, drainage, pruning, thinning, shading and other means and using pesticides as required. Apart from the conventional techniques, the management plan also involves anticipating diseases, defining economic thresholds and monitoring environmental parameters such as temperature, moisture, pH, nutrients, *etc*. The effectiveness of any disease control program depends on an agricultural production system that closely aligns with the goals of pest management. From the very start, care must be taken to select high quality and effective seeds, time to time disease and pest monitoring till harvest, proper transplantation to avoid shock in the field, appropriate variety selection, irrigation targeting reduction of leaf wetness, recommended doses of fertilizer, need based use of pesticides, harvesting at the right time and proper storage and shipping methods to maintain the shelf life and quality of produce (Kakraliya *et al.*, 2020). The term "Integrated Disease Management" (IDM) describes a thorough and all-encompassing method of managing and controlling diseases in a diverse manner. It entails combining various approaches, specialities and methods to handle the various facets of disease monitoring, diagnosis, treatment and prevention. IDM seeks to minimise the effects of diseases on people, communities and agricultural systems while optimising disease control efforts through the combination of diverse methods and approaches (Pandey *et al.*, 2016).

2. Advantages of Integrated Pest Management

a) *Sustainable Agriculture*: In contemporary farming, sustainable agriculture is essential because it prioritises meeting current needs without compromising the capacity of future generations to fulfil their own. Keeping diseases under control is a major challenge in sustainable agriculture since they can seriously harm crops and lower harvests. IDM promotes integration of several management practices which not only reduces the dependence on chemicals but also maintains a healthy ecosystem.

b) *Disease Resistance and Outbreaks*: Plant disease outbreaks reduce primary productivity and biodiversity, which negatively impacts the socioeconomic and environmental aspects of the impacted areas. The integration of several disease management ideas into research will enhance our mechanistic comprehension and forecast of pathogen dissemination in future.

a) *Healthy Ecosystem*: Integrated Disease Management reduces the use of chemicals in the cropping system promoting healthy ecosystem and less harm to the environment maintaining the global food security.

b) *Cost and Labour Effective*: Timely preventive measures like the cultural control practices, disease resistant varieties used in agriculture reduces the cost of disease management by keeping the crop free of diseases (Khoury *et al.*, 2010).

c) *Climate Resilient*: IDM encourages a flexible and diverse agricultural system, which is essential for meeting the demands of the changing environment and new diseases. Farmers who use flexible disease control techniques are better able to adjust to shifting environmental conditions. To simulate future disease epidemic scenarios, disease-forecasting models that rely on weather data can be coupled with other management approaches

(Coakley *et al.*, 1988).

3. Principles of Integrated Disease Management

a) Disease Avoidance: Disease can be avoided by altering the host plants' cultivation pattern both spatially and temporally by varying the planting time, location, or approach. This strategy seeks to avoid the disease by non-synchronizing the susceptible crop stage and the growth of the pathogen necessitizing a good understanding of host sensitivity through various phenological developmental stages, probable weather patterns, disease ecology and pathogen and pathotype distributions.. When it comes to spread by insect vectors, disease prevention requires an understanding of the ecology of the insects, including their overwintering location, migrating patterns, wind direction, and reproductive biology.

b) Exclusion: The goal of these precautions is to keep the inoculum from spreading or growing in a field or other place where it is not present. Plant quarantine regulations, seed treatment and seed inspection and certification are a few different exclusion strategies. The crop will be certified as disease-free once the necessary measures have been taken to remove the affected plants as soon as possible. Plant quarantine regulations are very crucial and applicable to nations like India, whose economies are mostly dependent on agriculture. In addition to reducing the threat posed by exotic pests and diseases, quarantine works to eradicate the spread of diseases and pests, both native and imported, that have a limited range within the nation (domestic quarantine).

c) Eradication: The practice of eliminating inoculums at their source—from a particular plant or from an area where they have already established themselves is known as eradication. Certain techniques produce excellent results for managing plant diseases with negligible to no negative ecological effects by removing or decreasing inoculum sources that eradicate overwintering sites of pathogens as well as their vectors of transmission. The main challenge in managing plant diseases is identifying the right primary inoculum source.

d) Protection: Plants can be protected from infection by preventing wind-borne pathogen inoculums from fields or any other far-off area of survival to the host location. Toxic barriers placed between the inoculums and the plant surface can be used to achieve this. Chemical sprays, dusts, environment alteration and host nutrition modification are some other techniques used to protect the plants from diseases.

e) Host Resistance: It makes use of built-in mechanisms to disrupt the disease causing capacity of the pathogen. Abiotic and biotic factors can also be used and manipulated to generate host resistance in plants. Chemotherapy or genetic engineering can also be used to make the infection or pathogen-induced damage ineffective. Resistant cultivars of numerous economically significant crops are being created by utilising several biotechnological techniques including tissue culture, genetic editing and protoplast fusion In addition to these, crop types resistant to a particular pathogen or combination of pathogens have been developed with the aid of plant breeding techniques such as selection, mutation and hybridisation.

f) Therapy: Therapy is considered as a curative process where chemical and physical treatments are employed to either heal or revitalise the infected host plant. In Integrated Disease Management, holistic management strategies comprising of cultural, biological and chemical methods are used to combat the pathogens (Agrios, 2005).

4. Tools/Components of Integrated Disease Management

4.1. Cultural Control

Cultural control practices or cultural control may be defined as strategies taken to make the cropping environment beneficial for the crop and unfavourable to the pathogen. Reducing stress on plants by altering their surroundings encourages healthy plants and helps lessen the harm caused by various plant diseases. Cultural control practices manipulate the crop environment to make it less conducive to the pathogen by using techniques like crop rotation, crop combination, irrigation, green manuring, planting time, plant spacing and season adjustments, either on their own or in conjunction with other methods. In addition to maintaining the healthy growth of the crop, cultural control techniques directly lower the potential of inoculums directly and increases the biological activity of soil antagonists through solarisation, crop rotation and other means.

a) Deep ploughing physically kills the pathogen when the crop is exposed to high temperatures. This is also known as dry soil solarisation. Wheat yield was increased and cyst nematode populations were effectively reduced by summer ploughing.

b) Field flooding resembles to soil disinfestation. Long-term summer soil flooding has been shown to reduce soil-borne pathogen populations, either with or without paddy culture.

c) Infectious plant diseases can be managed with the use of proper sanitation practices that exclude, minimise, or eradicate pathogen populations. Uses of naturally resistant or tolerant varieties are always recommended decreasing the need for chemical interventions.

d) Dispersal of soil borne pathogens from one field to the next can be minimised by ensuring proper cleaning of farm equipment and stakes. Crop rotation and the removal of volunteer plants can reduce the persistence of pathogens from one growing season to the next (Kumar *et al.*, 2019).

e) To lessen the chance of pathogens spreading, soil movement from one location to another should be prevented. For instance, polluted soil is the primary means of transportation for the sclerotia of *Sclerotinia sclerotiorum* and *Sclerotium rolfsii*. Reducing injuries during harvest and packaging also lessens the risk of postharvest diseases. Soil solarisation can help achieve some degree of soil sanitation, depending on crops and other conditions.

f) Crop rotation is a crucial technique, particularly used to manage diseases which are soil-borne. A minimum three-year rotation utilising a non-host crop significantly lowers pathogen attack for numerous soil-borne diseases. For Fusarium wilt of watermelon and blight of pepper caused by Phytophthora, this method is helpful; nevertheless, prolonged rotation times (up to 5-7 years) might be required. Avoiding recently cultivated land for reservoir and alternate hosts is advised whenever feasible. The selection of location for vegetable field should be such that it is free from sources of inoculum and insect vectors.

g) The management of viral infections depends on weed control. It is possible that numerous significant viruses have secondary or auxiliary hosts in weeds. Weed removal reduces the primary inoculum. Growing of cover crops will reduce the weed population and the initial inoculum of a number of pathogens.

h) Pathogens, especially bacteria, may spread through excessive plant handling procedures like thinning, trimming and tying. Avoiding circumstances that encourage plant damage is important since some infections can only reach the host through wounds.

i) Soil aeration and drying can be improved by adding composted organic amendments to the soil. After harvesting, the remaining healthy and diseased plant material can be removed to reduce the pathogen inoculum.

j) Polythene mulch serves as a physical barrier between soil and above ground plant components preventing fruit rot in vegetable fields. Mulches that are highly UV-reflective (metallized) also deter insects acting as vectors of viral diseases (Rasool *et al.*, 2022).

4.2. Physical Control

Techniques for physical control are useful for managing several diseases. These techniques make use of physical tools and barriers to manage and spread diseases.

a) Heat can be applied to treat soil, plant material, or equipment to eradicate pathogens. Temperature regimes are carefully chosen to ensure pathogens are successfully eliminated without causing harm to the treated material. Seed- borne diseases and infected seeds can be treated with hot water to eliminate associated pathogens. In case of loose smut of wheat, seeds should be treated for a temperature of 52 °C for 11 min. Hot water treatment can effectively used to treat leaf scald (50 °C for 2-3 h), red rot (54°C for 8 h), ratoon stunting of sugarcane (50 °C for 3 h), black rot of crucifer (50 °C for 20-30 min) *etc.* Infected seeds can be submerged in hot water for the recommended temperature and duration. Hot air treatment 35-54 °C for 8 h is recommended in case of several dormant virus infected plants. Fungal and bacterial diseases occurring mostly due to accumulation of moisture in the plant organs can be treated with hot air treatment.

b) By the method of soil solarisation with transparent plastic sheets, soil temperature is raised to a point where pathogens found in the uppermost layers can be killed. This technique works especially well in warm regions.

c) Sterilisation techniques like administering chemicals to eradicate bacteria, heating, or radiation are frequently employed to sanitise surfaces, instruments and equipment to stop the spread of disease.

d) The most widely used technique for preventing post-harvest infections in perishable fruits and vegetables is refrigeration, or low temperature treatment.

e) Management of insect vectors is very crucial for preventing viral diseases. Insect vectors can be checked by employing a range of traps, such as yellow sticky traps and blue traps for aphids, whiteflies and thrips (Razdan and Sabitha, 2009; Gupta *et al.*, 2023; Huded *et al.*, 2023).

4.3. Biological Control

The demand for the use of biocontrol techniques in disease management is increasing tremendously particularly among organic growers. Biological Control are an effective method of managing insects because they offer the right amounts of pest control with minimal environmental harm and no harm to other non-target organisms. Biological control of diseases with biopesticides can efficiently reduce the population of pests below levels that cause economic harm. These are naturally occurring compounds formed from microbes or their products and by-products that contain bacteria, viruses, nematodes and fungus as the primary active components (Dutta *et al.*, 2023). Before implementing biocontrol management strategies, especially in cases of widespread disease, a better understanding of the interactions between plants and pathogens as well as the environmental factors that are common in a particular area must be acknowledged. Numerous agonistic and antagonistic interactions between bacteria in the rhizosphere and phyllosphere and plants are necessary for biological management, which uses these interactions to reduce illness and control pests. Rhizospheric organisms can be introduced into the field from outside sources (the silver bullet strategy) or harvested from the surrounding environment (the black box approach) (Mishra *et al.*, 2015). Biological control of diseases is brought about by the employment of microorganisms, nematodes and plant products. *Trichoderma viride/ harzianum*, *Gliocladium virens*, *Streptomyces griseoviridis*, *Beauveria bassiana*, *Pseudomonas flourescens*, *Bacillus subtilis* are a few examples of commercially accessible bio control agents. It has been discovered that phages, or bacteria, are an efficient biocontrol tool for controlling tomato bacterial spots. *Paecilomyces lilacinus* associated with the rhizosphere of several crops has been isolated and has demonstrated encouraging results to control root-knot nematodes. Plant growth-promoting fungi (PGPF) (*Trichoderma*, *Penicillium*, *Aspergillus* and *Fusarium* spp.), activates the plant immune responses in order to combat pathogen attack. They are also regarded as one of the safest ways to promote crop plant growth and induce systemic resistance (ISR). Seed treatment, seedling dip and seed biopriming with fungal and bacterial cultures have increased the crop growth and crop yield by protecting them from phytopathogens. Root rot incidence of groundnut was found to be significantly reduced with seed treatment of *P. fluorescens* under field conditions (Meena *et al.*, 2001). Seed treatment of tomato with powder formulation of PGPR (*Bacillus subtilis*, *B. pumilus*) reduced severe symptoms of tomato mosaic virus along with increased fruit yield (Murphy *et al.*, 2000). Seedling dip treatment of rice with *P. fluorescens* helps to manage sheath blight of rice in field conditions (Nandakumar *et al.*, 2001). The technique of seed biopriming with microbial agents is used in several vegetable crops like tomato, brinjal, soybean and chickpea to protect them from seed borne diseases (Mishra *et al.*, 2001). In bioprimed seeds of chickpea and rajma in pots and fields, three rhizosphere-competent microbial strains, *P. fluorescens* OKC, *Trichoderma asperellum* T42 and *Rhizobium* sp. RH4, individually and in combination demonstrated higher germination percentages and better plant growth in both crops when compared to non-bioprimed control plants. All of the combinations that included *Trichoderma* performed better than the others and the triple microbial combination produced the greatest results for both chickpea and rajma in terms of seed germination and seedling growth (Yadav *et al.*, 2013). Bean rust is significantly controlled with the application of *B. subtilis* to the leaves of beans (Tsegaye *et al.*, 2018). Another contemporary bio-control strategy for managing disease is cross-protection. This method involves inoculating the host plant with a moderate strain of virus or bacterium. These shield the host plants from viruses and microbes that could inflict far more serious harm, such as citrus tristeza disease, papaya ring spot disease, *etc.*

Plants and animals can both produce bioactive natural chemicals that have the capacity to manage plant diseases and stimulate plant growth. Several bioactive compounds like phenols, terpenoids, or alkaloid groups have been found to be useful as biopesticides in organic farming (Freeman and Battie, 2008). Plants that could be used as botanical insecticides are abundant in India. One such technique that makes use of different plant products to attain and guarantee optimum crop health is the use of botanical pesticides, which has grown significantly in importance in modern agriculture. The ability of higher plants ability to fend against diseases has long been linked to the existence of antifungal chemicals (Kurucheve *et al.*, 1997). These substances are thought to be useful for managing many plant diseases since they are biodegradable and selectively poisonous (Singh and Dwivedi, 1987). Among the botanical pesticides available, Neem, garlic, onion, ocimum, eucalyptus and other botanicals are some of the most often used plant disease management agents. Such botanical insecticides or botanicals suit the current needs and efficiently fit into the IPM idea. Leaf extracts of neem was found effective against a number of diseases like rust of groundnut, bean common mosaic virus, leaf spot of chilli, sheath rot of rice, alternaria leaf spot of mustard (Suresh *et al.*, 1997; Tripathi and Tripathi 1982; Maharishi 1993; Pramanick and Phookan, 1998). Neem seed kernel extract of neem suppresses and controls Early blight of potato, Leaf curl of Tomato, *etc*. (Somasekhara *et al*., 1998; Patil *et al*., 2003).

4.4. Chemical Control

Under IPM programs, which emphasise the sensible use of pesticides, pesticides are only to be used as a last resort due to their potential effects on human health, beneficial species and the environment. In agriculture, integrated disease management (IDM) emphasises non-chemical methods, while chemical controls are sometimes necessary. Appropriate application techniques, timing and dose modification are crucial to minimise side effects. When plant protection chemicals are used in controlling pathogens, they should be applied where they can come into contact with pathogen propagules or where the plant can absorb them and translocate them to other tissues at a concentration that is toxic to pathogens (Jorgensen *et al*., 2000). Choosing selective pesticides minimise the impact on beneficial microbes and non- target organisms by targeting specific pathogens. It is possible to reduce disease incidence and resistance by rotating different pesticide classes. A synergistic effect is produced when selective pesticides and biological treatments are used, improving overall disease management. Selecting pesticides with lesser toxicity and environmental persistence lessens their influence on the environment with the overarching objective of maintaining agricultural ecosystems' natural balance (Leadbeater *et al*., 2000).

5. New Approaches in Integrated Disease Management (IDM)

A revolution was seen in plant protection sector due to pesticide resistance, different market factors and the harmful consequences from pesticide use. In light of contemporary environmental concerns, integrated disease management (IDM) is one of the most suitable and pertinent approaches for successfully preventing plant diseases and increasing agricultural yields. This strategy requires the use of contemporary technology in IDM with a variety of cropping techniques. This scientific assessment of plant protection trends considers new mechanisms of action, pesticide residue concerns, new tools to prevent pathogen resistance and the emergence of new pathogen races, evaluation of novel biocontrol agents, state-of-the-art molecular tools, etc. The use of modern technical methods is growing in importance, especially the creation of novel, high-yielding cultivars resistant to disease, smart sprayers, and remote sensing instruments that enable precise and organised pathogen monitoring (Mukhtar *et al*., 2023). A technique that is frequently employed in pharmaceutics and other bio-analytical processes, metabolomics is now showing its value in the investigation of plant-pathogen interactions. In plant-pathogen interactions, metabolites have a variety of activities, including as antimicrobial activity, signal transduction, cell-to-cell signalling, surveillance against pathogen attack and enzyme control. Several metabolites associated with infection can be found using this method, including compounds produced by pathogens during colonisation, as well as amino acids and carbohydrates whose production is stimulated or mislocalized in the host to promote pathogen growth (Tsuge *et al.*, 2013).

The use of nanotechnology in disease diagnostics, pesticide delivery and plant infection therapy is growing. In order to attain food security with minimal environmental impact, there has been a major shift towards sustainable agriculture, which can be accomplished by employing nanomaterials as innovative nanofungicides and nanopesticides. Nanoparticles (NPs), nanoemulsions and nanocomposites are few examples of nanocarriers often used for managing phytopathogens (Dutta *et al.*, 2017).

There is an immediate need of a novel class of biocontrol agents that exhibit enhanced potency, elevated productivity in fermenters, extended stability and room temperature storage and superior compatibility with alternative control techniques. Standardising the protocol for BCA identification to combat pests and soil-borne diseases along with research on population genetics offers opportunities to get a better understanding of how to maximise the effects of biological control.

Investigating novel genomic technologies like as CRISPR genome editing can introduce new desirable qualities like disease resistance into biological control agents without reducing the number of favourable traits that exist already (Jaiswal *et al.*, 2022).

6. Conclusion

IDM promotes teamwork, sharing of knowledge, creativity and the use of best practices essential for maintaining food production, crop health and agricultural systems' sustainability. Sustainable plant disease management requires a multifaceted consideration of the effects of management approaches on economics, sociology, and ecology by fully understanding the mechanisms underlying plant disease epidemics, the functioning of robust agro-ecosystems, and the individual and collective approaches on disease management (Pandey *et al.*, 2016).

This plant disease management approach aims to safeguard natural resources and the ecological environment in addition to raising agricultural output and food quality. Resource-poor farmers must actively participate in developing locally tailored methods and solutions that fit their unique farming systems in order to implement Integrated Disease Management (IDM) strategies. They must also incorporate easily accessible and environmentally sound control elements. The success and sustainability of IDM initiatives depend on increasing farmer awareness and educating disease survey teams, agricultural development officers, extension agents, and policy makers (He *et al.*, 2016).

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