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A Comprehensive Review on Various Plant Diseases and Impact on Crop Yield and Quality

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ABSTRACT

Plant diseases present considerable risks to worldwide agriculture, resulting in major declines in agricultural output and quality. Comprehending the classifications, manifestations, and etiologies of these diseases is essential for formulating appropriate management strategies. This research offers an exhaustive examination of plant diseases, emphasizing fungal, bacterial, viral, nematode, and parasite infections, their routes of transmission, and the environmental conditions that affect disease outbreaks. The study is to examine the effects of plant diseases on agricultural output and investigate sophisticated detection and management strategies. A qualitative research methodology was employed, utilizing secondary data gathered from internet sources, encompassing peer-reviewed publications and conference proceedings published from 2018 to 2025. A total of 28 pertinent studies were examined to evaluate trends in disease onset, pathogen adaptation, and control strategies. The results demonstrate that climatic change, mono-cropping, and inadequate agricultural methods have intensified disease prevalence, resulting in heightened economic losses. Progress in molecular diagnostics, artificial intelligence, and integrated pest management (IPM) has demonstrated potential in enhancing early detection and sustainable control methods. Nonetheless, obstacles persist in attaining widespread implementation of environmentally sustainable alternatives. The research determined that effective plant disease management necessitates a multidisciplinary strategy, incorporating biotechnology, remote sensing, and regulatory measures. Fortifying international cooperation, augmenting farmer awareness, and investing in novel disease-resistant crops are essential for enduring agricultural sustainability. These findings have profound consequences for food security, economic stability, and environmental protection, underscoring the necessity for ongoing study and adaptive tactics to effectively combat plant diseases.

Keywords: Plant Diseases; Crop Yield Loss; Disease Management; Integrated Pest Management; Artificial Intelligence; Agriculture.

INTRODUCTION

Plant health is a cornerstone of global agriculture, directly influencing food security, economic stability, and environmental sustainability. Especially in areas mostly dependent on farming, healthy crops guarantee consistent agricultural productivity, which is necessary for feeding the world's rising population and enabling livelihoods [1, 2]. However, plant diseases pose a significant threat to agricultural systems, leading to considerable reductions in crop yield and quality. These diseases, caused by fungi, bacteria, viruses, nematodes, and parasitic organisms, can spread fast through numerous transmission mechanisms such as air, soil, water, and vectors like insects [3]. The repercussions of plant diseases are far-reaching, affecting not only farmers but also consumers and industries depending on agricultural produce. When diseases strike staple crops such as wheat, rice, maize, and potatoes, they can lead to food shortages, price fluctuations, and increased import dependency in affected regions [4, 5]. Moreover, plant diseases contribute to large financial losses, with farmers investing considerably in chemical treatments, disease-resistant seeds, and modern monitoring systems to limit their impact. In addition to economic difficulties, plant diseases pose environmental challenges, as excessive pesticide usage can deteriorate soil health, harm non-target organisms, and contribute to pesticide resistance among pathogens [6]. Climate change further exacerbates the problem by creating favourable conditions for the emergence and spread of new and more virulent plant

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pathogens. Given these challenges, a thorough understanding of plant diseases, their symptoms, and causative agents is essential for developing effective management strategies [4, 7]. The figure 1 below illustrates the pathology of plant in detail.

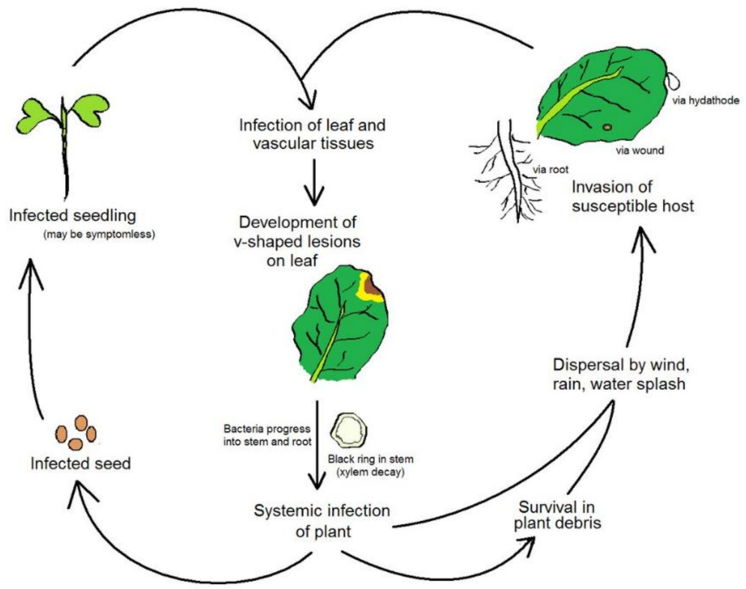

Figure 1: Pathology of plant – An overview

[1] https://en.wikipedia.org/wiki/Plant_pathology#/media/File:Black_rot_lifecycle.tif

This review paper categorizes plant diseases by pathogens and transmission routes and examines their effects on crop productivity and quality. It also examines environmental and agricultural factors that cause disease outbreaks and analyses present and future management approaches, including as chemical, biological, and advanced technological treatments like artificial intelligence and remote sensing. A qualitative research approach was used to assess secondary data from peer-reviewed publications and studies published between 2018 and 2025 to discover plant disease research trends and advances. The findings emphasize the necessity for coordinated disease control that balances productivity and environmental conservation.

CLASSIFICATION OF PLANT DISEASES

Plant diseases can be categorized according to their causative pathogens and transmission methods, with each impacting crops in unique manners. Pathogen-based classification encompasses fungal, bacterial, viral, nematode, and parasitic plant diseases, each presenting distinct symptoms including wilting, leaf spots, stunting, and chlorosis. These diseases disseminate through multiple routes, including airborne spores, contaminated soil, infected seeds, and vector organisms such as insects and nematodes. Transmission-based classification categorizes diseases as airborne, soil borne, waterborne, or vector-borne, based on the pathways via which pathogens infect host plants [8, 9]. Airborne illnesses disseminate through wind and precipitation, but soil borne pathogens endure in the soil, infecting plants via their roots. Waterborne diseases utilize irrigation or surface water as vectors, while vector-borne diseases rely on insects and nematodes for transmission. The subsequent table offers a comprehensive overview of plant disease classification, detailing their symptoms, instances, and modes of transmission to elucidate their effects on agriculture.

Table 1: Classification of Plant Diseases [8, 9, 10, 11]

CATEGORY	COMMON SYMPTOMS	EXAMPLES	TRANSMISSION & DISEASE CYCLE
Based on Pathogens			

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Research Article

Fungal Diseases	Wilting, leaf spots, rots	Rust, Powdery Mildew, Blight	Spread through spores in air, soil, or water; fungi penetrate plant tissues and reproduce rapidly in humid conditions.
Bacterial Diseases	Leaf blights, soft rots, wilting	Bacterial Wilt, Citrus Canker, Fire Blight	Enter plants through wounds or natural openings; spread via rain splash, insects, and contaminated tools.
Viral Diseases	Mosaic patterns, stunting, yellowing	Tobacco Mosaic Virus, Rice Tungro Disease	Transmitted through insect vectors, infected seeds, or mechanical means such as human handling.
Nematode Diseases	Root galls, stunted growth	Root-Knot Nematode, Cyst Nematodes	Nematodes invade roots, reducing nutrient uptake; spread through contaminated soil, tools, and water.
Parasitic Plant Diseases	Chlorosis, growth reduction	Dodder, Mistletoe, Witchweed	Parasitic plants attach to host plants, extracting nutrients; seeds spread via animals, wind, and water.
Based on Mode of Transmission			
Airborne Diseases	Dispersed by wind and rain	Rust, Downy Mildew	Fungal spores travel through the air and land on host plants, infecting susceptible tissues.
Soilborne Diseases	Transmission through infected soil	Fusarium Wilt, Root Rot	Pathogens persist in soil and infect plants via roots, leading to vascular blockage and decay.
Waterborne Diseases	Spread through irrigation and surface water	Bacterial Soft Rot, Phytophthora Blight	Water carries pathogens that enter plants through wounds or natural openings.
Vector-Borne Diseases	Insects and nematodes act as carriers	Yellow Leaf Curl Virus (whiteflies), Rice Tungro Virus (leafhoppers)	Pathogens rely on insect vectors to move between plants; insects acquire and transmit diseases while feeding.

SYMPTOMS AND DISEASE DIAGNOSIS

Precise diagnosis of plant diseases is essential for effective management and mitigation; as early detection can avert extensive crop damage. Disease signs may be classified into visual, molecular, and sophisticated technology diagnostics. Visual symptoms are the predominant markers of plant disease, with afflicted crops displaying leaf spots, chlorosis, necrosis, wilting, and atypical growth patterns. The symptoms differ according to the pathogen type; for example, fungal infections typically result in powdery or downy mildew, bacterial diseases cause soft rots and blights, and viral infections present as mosaic patterns and stunted development [12, 13]. Although visual inspection is

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Research Article

commonly employed, it frequently proves inadequate for accurate pathogen identification because of the symptomatological similarities among many infections.

Molecular and laboratory diagnostics are utilized to improve accuracy, employing techniques such as Polymerase Chain Reaction (PCR) for pathogen DNA detection, Enzyme-Linked Immunosorbent Assay (ELISA) for the identification of pathogen-specific proteins, and DNA barcoding for species-level identification. These approaches facilitate precise and swift detection, allowing for prompt intervention [14]. Nonetheless, their extensive adoption is frequently constrained by expense, technical proficiency, and the necessity for laboratory infrastructure, rendering them less attainable for small-scale farmers.

Advancements in technology have led to the emergence of remote sensing and AI-based disease diagnosis as formidable instruments in plant pathology. Remote sensing use multispectral and hyperspectral imaging to identify plant stress and disease indicators prior to their visibility to the unaided eye. AI-driven methods, encompassing deep learning and computer vision methodologies, scrutinize extensive datasets derived from drone and satellite imagery to accurately identify areas affected by disease. These automated methodologies provide extensive surveillance and early alert systems, enhancing disease forecasting and management. Integrating traditional and modern diagnostic procedures can yield a complete and efficient framework for plant disease identification, so maintaining sustainable agricultural practices and food security [15, 16].

FACTORS INFLUENCING DISEASE DEVELOPMENT

The progression of plant diseases is affected by a confluence of environmental factors, agricultural methodologies, and pathogen evolution, each significantly impacting the intensity and dissemination of illnesses. Comprehending these aspects is crucial for formulating efficient disease management methods to guarantee sustainable agriculture and food security.

1. Environmental Factors

The life cycle and proliferation of plant diseases are significantly influenced by environmental factors like temperature, humidity, rainfall, soil quality, and temperature. Many fungal and bacterial pathogens flourish in warm, humid environments, so tropical and subtropical areas are quite prone to plant illnesses. While too much rain helps waterborne diseases to proliferate, high humidity provides a suitable habitat for fungal spores to germinate. On the other hand, dry conditions reduce plant immunity, therefore increasing crop susceptibility to diseases. Furthermore, affecting disease development is soil health and nutrient availability since plants lacking nutrients are less able to protect themselves against infections. Inappropriate nutrient levels and poor soil structure can lead to stress conditions that increase a plant's susceptibility to diseases. For example, a lack of potassium weakens plant cell walls, which increases their susceptibility to fungal attacks; on the other hand, too much nitrogen encourages too much vegetative development, therefore raising the risk of pest and disease outbreaks [17]. The figure 2 illustrates the environmental factors that influence plant disease development in detail.

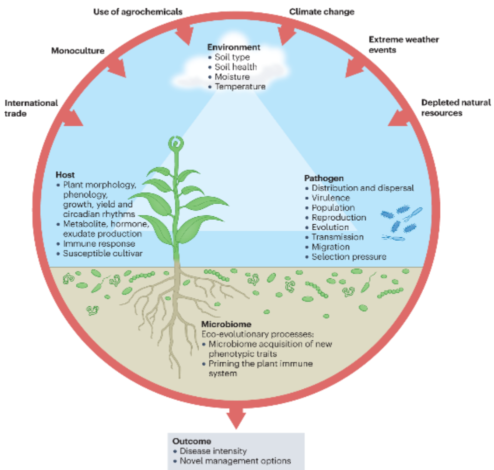

Figure 2: Environmental Factors that influences plat disease development – An overview [17]

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Research Article

2. Agricultural Practices

Particularly with intensive farming techniques, modern agricultural technologies can produce conditions fit for the propagation of plant diseases. Mono-cropping—that is, the widespread, continuous cultivation of the same crop species—depletes soil nutrients and promotes the growth of certain diseases targeted at those crops. This habit disturbs natural systems of disease control and lowers biodiversity. By producing soggy conditions that encourage soil borne pathogens including Phytophthora and Pythium, which cause root rot, poor irrigation and drainage systems further aggravate disease frequency [18]. Furthermore, adding to the entrance and quick spread of illnesses in agricultural systems are the use of contaminated seeds and planting materials. Unknowingly planting sick seeds, farmers may cause extensive crop failure resulting in financial losses. Using certified disease-free seeds, good water management, and crop rotation will help to greatly reduce these hazards. The figure 3 below illustrates the agricultural factors affecting the plant disease development in detail.

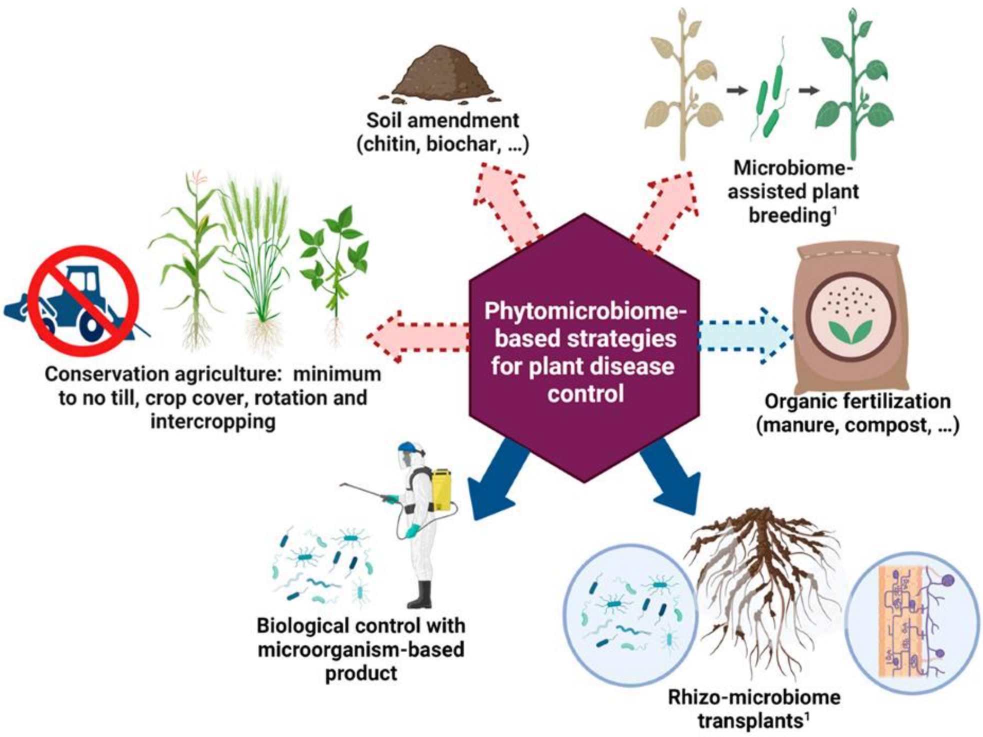

Figure 3: Agricultural Factors – An overview [18]

3. Pathogen Evolution and Resistance

Pathogens perpetually adapt, acquiring novel mechanisms to infect plants and evade current management strategies. Mutations and genetic recombination facilitate the creation of novel disease types exhibiting increased virulence and resistance to insecticides or fungicides. The overuse of chemical treatments hastens this process, resulting in the emergence of resistant pathogen strains, hence complicating disease management. Repeated treatments of fungicides have resulted in the emergence of fungicide-resistant strains of Botrytis cinerea and Phytophthora infestans. Viruses like the Tomato Yellow Leaf Curl Virus (TYLCV) have developed novel strains that circumvent plant resistance genes, presenting a considerable obstacle to disease management initiatives [19]. The ongoing evolution of pathogens requires the formulation of comprehensive disease management methods that incorporate genetic resistance, biological control, and sustainable agricultural practices to reduce outbreak risks and maintain long-term crop health. The figure 4 below illustrates the Pathogen Evolution and Resistance in detail.

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Research Article

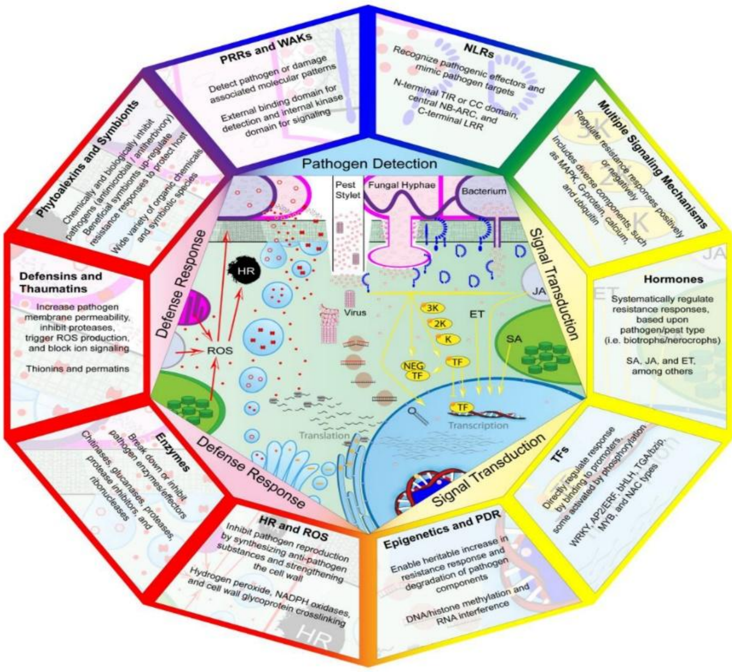

Figure 4: Pathogen Evolution and Resistance – An overview [19]

IMPACT OF PLANT DISEASES ON CROP YIELD AND QUALITY

Plant diseases significantly impact agriculture, directly influencing crop output, quality, and economic stability. The intensity of these effects is contingent upon factors like the pathogen kind, environmental conditions, and the efficacy of disease management techniques. Comprehending these ramifications is essential for formulating sustainable farming methods and alleviating threats to food production.

1. Direct Yield Loss

Stunted growth, leaf defoliation, and root damage from plant diseases reduce crop yield immediately. Many diseases impair plant physiological functions, reducing biomass and fruit or grain yield. Powdery Mildew and Late Blight reduce plant photosynthesis. Bacterial Wilt can kill a plant, while Rice Tungro Virus causes seed sterility and unfilled grains [20]. Several diseases damage fruit, making it unfit for sale or eating. Infected plants produce fewer, smaller fruits, reducing harvest yields. The drop in productivity threatens farmers' income and food supply, especially in agricultural areas.

2. Quality Deterioration

Plant diseases reduce crop yield and quality, affecting nutrition, flavour, and appearance. Certain viruses reduce vitamin absorption, reducing the nutritional value of contaminated vegetables. Some fungal infections cause mycotoxin contamination in wheat and maize, rendering them unsafe to eat. Black Rot in grapes and Anthracnose in mangoes cause flaws and degradation, making them undesirable to consumers and lowering their market value [21]. Farmers lose money and suffer post-harvest losses when commercial marketplaces reject substandard output. These considerations emphasize the need for early disease detection and intervention to protect crop quality and consumer confidence.

3. Economic Consequences

Plant diseases affect national and international trade beyond farmers. Pesticide treatment, laborious disease control, and crop replanting raise production costs for farmers. When importing nations take strict phytosanitary procedures to prevent disease spread, severe disease outbreaks might hinder global trade. Citrus crops face limits from Citrus Canker and Huanglongbing (Citrus Greening Disease), hurting international trade. Economic pressures may raise food prices, hurting producers and consumers [22].

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Research Article

4. Impact on Food Security

Plant diseases threaten food security, especially in poorer countries where agriculture is the main industry. Pathogen-induced yield losses reduce food supplies, causing price swings and hunger. Rice, wheat, and maize disease outbreaks can disrupt food systems and affect millions. Crop quality decline may limit availability to nutrient-dense diets, worsening malnutrition [23]. Disease control must be improved through resistant crop types, enhanced monitoring systems, and sustainable agriculture to ensure food security.

DISEASE MANAGEMENT STRATEGIES

Effective treatment of plant diseases is crucial for maintaining sustained agricultural output, ensuring food security, and promoting economic stability. Effective disease control necessitates a comprehensive approach that incorporates preventive, chemical, biological, and technological measures. Through the implementation of these strategies, farmers can mitigate crop losses, preserve soil health, and diminish dependence on detrimental pesticides.

1. Preventive Approaches

Preventive techniques are essential in plant disease control, as they diminish the probability of infections prior to their onset. Crop rotation and mixed farming disrupt disease cycles by preventing pathogens from repeatedly attacking the same plant species. For instance, intercropping legumes with grains enhances soil vitality and diminishes the accumulation of soil borne pathogens. Genetically modified disease-resistant cultivars offer an efficient preventive strategy, allowing plants to withstand fungal, bacterial, and viral diseases. Biotechnology advancements have facilitated the creation of crops resistant to severe diseases like Wheat Rust and Rice Blast. Soil and water management are essential; as inadequate drainage can result in waterborne infections such as Phytophthora Blight. By implementing enough irrigation and soil aeration, farmers can establish circumstances that are detrimental to pathogens [24]. Moreover, biocontrol agents and natural predators, including beneficial fungi (Trichoderma) and bacteria (Bacillus subtilis), effectively mitigate disease populations in an environmentally sustainable manner.

2. Chemical Control Methods

Chemical treatments are extensively utilized for managing plant diseases; nevertheless, their application must be prudent to prevent resistance and environmental harm. Fungicides, bactericides, and nematicides precisely target specific pathogens. Copper-based fungicides are frequently employed to control Citrus Canker, whereas systemic fungicides inhibit Downy Mildew in grapes. Excessive chemical use might result in pesticide resistance, when bacteria adapt to endure treatments, hence complicating disease management. Moreover, excessive pesticide application has environmental consequences, polluting soil and water resources while adversely affecting beneficial creatures such as pollinators and soil bacteria [25]. To prevent these dangers, farmers must implement integrated strategies that combine chemical treatments with sustainable practices to ensure long-term effectiveness.

3. Biological and Integrated Pest Management (IPM)

Biological control and Integrated Pest Management (IPM) serve as sustainable alternatives to chemical approaches, emphasizing natural processes to mitigate plant diseases. Beneficial bacteria, including Pseudomonas fluorescens and mycorrhizal fungi, augment plant immunity and inhibit pathogenic activity. Companion planting and natural repellents provide supplementary protection, as certain plants emit biochemical that repel pests and pathogens. For example, cultivating marigolds in proximity to tomatoes diminishes worm infections, whilst neem extracts function as organic fungicides. Moreover, genetic engineering and CRISPR methodologies offer novel possibilities through the alteration of plant genomes to improve disease resistance [26]. CRISPR technology has facilitated the creation of virus-resistant cassava and blight-resistant potatoes, markedly diminishing production losses. These biotechnology solutions enhance long-term agricultural sustainability by reducing reliance on synthetic chemicals.

4. Advanced Technologies in Plant Disease Management

The incorporation of advanced technologies has transformed plant disease identification and management, improving accuracy and effectiveness. Artificial intelligence and machine learning facilitate early illness diagnosis using picture identification and predictive modelling, enabling farmers to recognize signs prior to their proliferation.

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Research Article

AI-driven applications, including Plantix and Agrosmart, aid farmers in identifying plant diseases and proposing treatment strategies. Drones and remote sensing have enhanced field monitoring by delivering real-time data on crop health and identifying disease outbreaks via multispectral imagery. These technologies provide focused treatments, minimizing superfluous pesticide applications and enhancing resource allocation. Another hopeful innovation is nanotechnology, which involves the engineering of nanoparticles to deliver disease-fighting medicines directly to sick plant tissues [24, 25, 26]. Silver and copper nanoparticles demonstrate potent antibacterial capabilities, providing an innovative method for addressing bacterial and fungal diseases. Ongoing research and technical progress will enhance the efficiency, sustainability, and environmental friendliness of plant disease management, hence safeguarding global food security.

CASE STUDIES OF MAJOR PLANT DISEASES

Historically, plant diseases have precipitated catastrophic agricultural crises, resulting in economic losses, food shortages, and notable scientific progress in disease management. Numerous significant plant diseases have exerted considerable worldwide effects, underscoring the imperative for effective disease management measures. Wheat rust, induced by Puccinia fungus, markedly diminishes global wheat yield. The most alarming variation, Ug99, originated in Uganda in 1999 and has disseminated across several continents, surpassing resistant wheat cultivars. The affliction debilitates wheat stems, diminishing production and heightening lodging hazards. Research institutions such as CIMMYT have engineered multi-gene resistant wheat varieties to mitigate its proliferation; however, ongoing surveillance and breeding initiatives are essential to avert food crises [28].

Late blight, attributed to Phytophthora infestans, was the cause of the Irish Potato Famine in the mid-19th century. The ailment disseminates swiftly in humid environments, resulting in foliar deterioration and tuber rotting. Notwithstanding contemporary fungicides and resistant potato cultivars, the disease persists in evolving, necessitating integrated management strategies that amalgamate genetic resistance, crop rotation, and precision agriculture for efficacious control [28]. Huanglongbing (HLB), often known as citrus greening, is a bacterial affliction transmitted by psyllid insects. It induces fruit malformations, an acrid flavour, and early fruit abscission, severely impacting citrus businesses in the United States, Brazil, and China. Management strategies encompass the regulation of insect vectors, the elimination of affected trees, and the creation of genetically modified citrus types with resistance. Panama disease, induced by Fusarium oxysporum, endangers worldwide banana cultivation, especially the Cavendish cultivar. The disease disseminates via soil and water, lacking an efficacious chemical remedy. Developing resistant types and enhancing biosecurity protocols are crucial for averting its worldwide dissemination. Rice blast, induced by Magnaporthe oryzae, impacts rice cultivation globally, diminishing yield by as much as 30%. Resistant rice varieties, fungicides, and precision agriculture technology are essential in alleviating its effects.

EMERGING CHALLENGES AND FUTURE PERSPECTIVES

Climate change, changing pathogens, and the necessity of sustainable control methods provide growing difficulties for management of plant diseases. Changing temperature, humidity, and rainfall patterns brought on by climate change makes new and more virulent plant diseases more suited for existence. Rising temperatures have increased the geographic range of pests and diseases, hence causing outbreaks in once unaffected areas. Furthermore, weakening plant resistance and increasing their susceptibility to diseases is the rising frequency of severe weather events such floods and drenches.

Creating environmentally friendly disease management plans is absolutely vital if they are to solve these problems. Dependency too much on chemical pesticides has resulted in environmental damage, pathogen resistance, and hazards to human health. Future strategies must stress biological control techniques including the use of genetically modified disease-resistant crops, biofungicides, and helpful bacteria. Promising early illness diagnosis and targeted treatments come from developments in nanotechnology, artificial intelligence, and precision agriculture. Moreover, exchange of knowledge, resources, and innovative technologies depends on worldwide cooperation in plant disease research. Policy frameworks, data-sharing platforms, and strengthening of international networks help to improve early warning systems and coordinated reactions to newly developing plant diseases. Ensuring world food security and sustainable development will depend on a multidisciplinary strategy combining biotechnology, climate science, and agronomy.

CONCLUSION

In conclusion, plant diseases provide considerable risks to global food security, economic stability, and environmental sustainability. This overview delineates the principal kinds of plant diseases, their effects on crop output and quality, and the imperative for effective management measures. Interdisciplinary research in plant pathology, incorporating biotechnology, artificial intelligence, and climate science, is crucial for formulating sustainable solutions. A transition to environmentally sustainable disease management, augmented biosecurity protocols, and strengthened international cooperation is essential. To guarantee enduring agricultural resilience, governments, researchers, and farmers must emphasize sustainable practices, utilizing new technologies and cooperative initiatives to address the ever changing challenges posed by plant diseases.

REFERENCES

[1] Liliane, T. N., & Charles, M. S. (2020). Factors affecting yield of crops. Agronomy-climate change & food security, 9, 9-24.
[2] Nazarov, P. A., Baleev, D. N., Ivanova, M. I., Sokolova, L. M., & Karakozova, M. V. (2020). Infectious plant diseases: Etiology, current status, problems and prospects in plant protection. Acta naturae, 12(3), 46.
[3] Shoaib, M., Shah, B., Ei-Sappagh, S., Ali, A., Ullah, A., Alenezi, F., ... & Ali, F. (2023). An advanced deep learning models-based plant disease detection: A review of recent research. Frontiers in Plant Science, 14, 1158933.
[4] Hasan, R. I., Yusuf, S. M., & Alzubaidi, L. (2020). Review of the state of the art of deep learning for plant diseases: A broad analysis and discussion. Plants, 9(10), 1302.
[5] Domingues, T., Brandão, T., & Ferreira, J. C. (2022). Machine learning for detection and prediction of crop diseases and pests: A comprehensive survey. Agriculture, 12(9), 1350.
[6] Ahmad, A., Saraswat, D., & El Gamal, A. (2023). A survey on using deep learning techniques for plant disease diagnosis and recommendations for development of appropriate tools. Smart Agricultural Technology, 3, 100083.
[7] Albattah, W., Nawaz, M., Javed, A., Masood, M., & Albahli, S. (2022). A novel deep learning method for detection and classification of plant diseases. Complex & Intelligent Systems, 1-18.
[8] Saleem, M. H., Potgieter, J., & Arif, K. M. (2019). Plant disease detection and classification by deep learning. Plants, 8(11), 468.
[9] Li, L., Zhang, S., & Wang, B. (2021). Plant disease detection and classification by deep learning—a review. IEEE Access, 9, 56683-56698.
[10] Shruthi, U., Nagaveni, V., & Raghavendra, B. K. (2019, March). A review on machine learning classification techniques for plant disease detection. In 2019 5th International conference on advanced computing & communication systems (ICACCS) (pp. 281-284). IEEE.
[11] Saleem, M. H., Potgieter, J., & Arif, K. M. (2020). Plant disease classification: A comparative evaluation of convolutional neural networks and deep learning optimizers. Plants, 9(10), 1319.
[12] Hashimi, M. H., Abad, Q., & Shafiqi, S. G. (2023). A review of diagnostic techniques of visual symptoms of nutrients deficiencies in plant. IJO-International Journal of Agriculture and Research (ISSN 2814-189X), 6(02), 01-09.
[13] Ghimirey, V., Chaurasia, J., & Marahatta, S. (2024). Plant Nutrition Disorders: Insights from Clinic Analyses and Their Impact on Plant Health. Agriculture Extension in Developing Countries, 2(1), 09-17.
[14] Donoso, A., & Valenzuela, S. (2018). In-field molecular diagnosis of plant pathogens: recent trends and future perspectives. Plant pathology, 67(7), 1451-1461.
[15] Ali, Z. A., Deng, D., Shaikh, M. K., Hasan, R., & Khan, M. A. (2024). AI-Based UAV Swarms for Monitoring and Disease Identification of Brassica Plants Using Machine Learning: A Review. Computer Systems Science & Engineering, 48(1).
[16] Jafar, A., Bibi, N., Naqvi, R. A., Sadeghi-Niaraki, A., & Jeong, D. (2024). Revolutionizing agriculture with artificial intelligence: plant disease detection methods, applications, and their limitations. Frontiers in Plant Science, 15, 1356260.

[17] Singh, B. K., Delgado-Baquerizo, M., Egidi, E., Guirado, E., Leach, J. E., Liu, H., & Trivedi, P. (2023). Climate change impacts on plant pathogens, food security and paths forward. Nature Reviews Microbiology, 21(10), 640-656.
[18] Chen, W., Modi, D., & Picot, A. (2023). Soil and phytomicrobiome for plant disease suppression and management under climate change: A review. Plants, 12(14), 2736.
[19] Andersen, E. J., Ali, S., Byamukama, E., Yen, Y., & Nepal, M. P. (2018). Disease resistance mechanisms in plants. Genes, 9(7), 339.
[20] Bengtsson-Palme, J., Kristiansson, E., & Larsson, D. J. (2018). Environmental factors influencing the development and spread of antibiotic resistance. FEMS microbiology reviews, 42(1), fux053.
[21] Thangjam, B. (2025). Assessment of Farmers' Knowledge towards Sustainable Agricultural Practices (SAP) in Manipur. Indian Journal of Extension Education, 61(1), 55-60.
[22] Matthews, S., Siddiqui, Y., & Ali, A. (2025). Unleashing the power of bio-stimulants for enhanced crop growth, productivity, and quality: a comprehensive review. Journal of Plant Nutrition, 48(4), 703-725.
[23] Puente-Moreno, J., Garrido-Auñón, F., García-Pastor, M. E., Valero, D., & Serrano, M. (2025). The Renaissance of Polyamines: New Roles in Crop Yield and Quality Properties in Freshly Fruit. Agronomy, 15(1), 201.
[24] Roy, S., Mitra, P., Jana, S., Kandar, K., & Patsa, M. K. (2025). Innovative approaches in kidney disease management: Advances in therapeutics and treatment strategies. Innovative Medicines & Omics, 4969.
[25] Ravanbakhshian-HabibAbadi, R., Behbahani, M., & Mohabatkar, H. (2025). Evaluation of several strategies for controlling canker plant disease caused by Pseudomonas syringae. Molecular Biology Research Communications, 14(1), 1.
[26] Vincent, E. M., Hill, E. M., & Parnell, S. (2025). Modelling the effectiveness of Integrated Pest Management strategies for the control of Septoria tritici. bioRxiv, 2025-02.
[27] Chen, X. (2020). Pathogens which threaten food security: Puccinia striiformis, the wheat stripe rust pathogen. Food Security, 12(2), 239-251.
[28] Cucak, M., Sparks, A., Moral, R. D. A., Kildea, S., Lambkin, K., & Fealy, R. (2019). Evaluation of the 'Irish Rules': the potato late blight forecasting model and its operational use in the Republic of Ireland. Agronomy, 9(9), 515.