Review Article

Advance Techniques in Plant Disease Management

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Abstract

Plant diseases can reduce human food availability. Traditional methods of plant disease management faces problems due to climate change, fungicide resistance, pesticide residues and biodiversity loss. Plant pathology plays a vital role in identifying, understanding and controlling pathogens that affect crops. In this review, we delve into the diverse array of plant pathology techniques employed for disease management. Plant disease forecasting models can be used to predict plant diseases ahead of time. Protected cultivation combats climate change. It is necessary to find more evidence that plant pathogen diversity has a dilution effect on disease incidence. Deep learning-based disease diagnosis will help detect diseases faster. More hybrid fungicides should be developed to minimize fungicidal resistance problems. Computer science and IoT are increasingly being used to combat plant diseases. Transcription activator like effective nucleases (TALENs), Mega nucleases, zinc finger nucleases (ZFNs), clustered regularly interspaced short palindromic repeat (CRISPR) are some of different genome editing tools. Nano particles are effective, cheap and ecofriendly in combating microbes. Among the molecular methods of plant disease management, RNA interference-mediated gene silencing and genome editing with CRISPR is more promising in plant disease management.

Key words: Agriculture, plant diseases, remote sensing, computer science, nanotechnology, genome editing, protected cultivation, hybrid fungicides, molecular methods, gene silencing.

Introduction

Plant disease remains a significant threat to productivity of agricultural and global food security, causing sustainable economic losses[(1)]. Traditional methods of plant disease management faces problems due to climate change, fungicide resistance, pesticide residues and biodiversity loss. Effective disease management strategies are imperative to mitigate these challenges and ensure sustainable crop production. Plant pathology plays a vital role in identifying, understanding and controlling pathogens that affect crops. In this review, we delve into the diverse array of plant pathology techniques employed for disease management. The accuracy, effectiveness and environmental impact of traditional techniques of plant disease management have become less favourable. Advance technologies for plant disease management have emerged as a promising instrument to address these issues and transform the treatment of plant diseases[(2)]. The global demand for agricultural products exceeds the supply. The ultimate aim is to manage the production of agriculture commodities more efficiently without modern technology is not easy to reach this trend. Future plan of disease management should be strengthen to ensure food availability by overcoming the problems of low yield and challenges in an ecological, sustainable, environmentally viable and socially acceptable ways of crop production[(3)]. This review discusses various advanced techniques of plant disease management and future research need for that effective management.

Remote sensing

Early and accurate detection of pathogens can pose important role in plant disease management. Remote sensing technology is, which utilize satellite aircrafts and drones equipped with advanced imaging sensors have significantly advanced the field of plant disease surveillance by enabling large scale, monitoring of crops with high temporal and special resolution[(4)]. Several RS systems exist that may be used to monitor plant health and identify diseases. Various RS systems have been applied to the task of recording infection symptoms (scabs, pustules, etc.), physiological responses (pigment content, water content, etc.), and structural changes (canopy structure, landscape structure, etc.) brought on by plant diseases and pests in order to more effectively detect and monitor these threats[(5,6)]. Visible and near infrared (VIS-SWIR) spectral systems, fluorescence and thermal systems, synthetic aperture radar (SAR), light detection and ranging equipment (Lidar) systems are the three main types of sensing systems for plant diseases and pest monitoring based on sensing principles. In general, sensors that detect wavelengths shorter than the visible spectrum (such as gamma rays, X rays, UV rays) are active, making them impractical for use in a mobile setting. These sensors are typically employed for indoor testing of plant diseases and pests, especially in edible (eaten raw) plants like vegetables and fruits. It is necessary to identify efficiently unique RS features to implement RS observations in plant disease and pest monitoring. Many other RS traits have been suggested or identified to use in identifying plant disease and pest symptoms and mapping plant distributions. Spectrum features in the visible and near-infrared range, fluorescence and thermal ranges, and the features in images and landscapes are the primary aspects of RS[7]. Moreover, remote sensing offers a rapid, non-invasive, and reasonably economical approach for investigating the biophysical and biochemical characteristics of vegetation across extensive spatial regions[8]. It serves as a valuable resource, particularly in regions lacking detailed maps, by providing essential data for land-use and spatial planning[9]. Additionally, remote sensing, including aerial photography, plays a crucial role as input for modeling various alternative land use scenarios[9].

The primary advantage of remote sensing lies in ability to non-destructive leaves, assess plant health and detect early disease symptoms over extensive area which is especially useful in large scale agriculture systems. Satellite remote sensing has been widely used for disease surveillance due to its ability to monitor large geographic area over time. eg.- hyper spectral and multispector satellite data have been successfully used to detect *cercospora* leaf spot in sugar beet[10].

Computer science and IoT in plant diseases management

Computer science and IoT (Internate of Things) are increasingly being used to combat plant diseases. The combination of computer science techniques, such as machine learning and data analysis, with IoT devices has the potential to revolutionize the way we detect and prevent plant diseases. By continuously monitoring plant health, IoT devices can detect the early signs of diseases and alert farmers, enabling them to take swift action. Additionally, the use of big data analytics can help researchers identify patterns and develop predictive models, which can ultimately lead to more effective disease prevention and control strategies.[11]

Genome editing

Genome editing is type of genetic engineering in which DNA is inserted, deleted or replaced in the genome of a living organism using engineered nucleases. Transcription activator like effective nucleases (TALENs), Mega nucleases, zinc finger nucleases (ZFNs), clustered regularly interspaced short palindromic repeat (CRISPR) are some of different genome editing tools. The improvement of rice blast resistance by engineering a CRISPR / Cas 9 SSN targeting the OsERF922 gene in rice, result revealed that blast lesions significantly decrease in engineered line compared to the wild type plants.[12]

Hybrid fungicides

Fungicides which unites the disease fighting power of botanicals and conventional chemistry are known as hybrid fungicides. Protective foliar applications of difenconazole and tea tree oil (TTO) in field trials where highly effective in controlling scab of apples and generally provided significantly higher disease control than difenconazole alone[13]. Tea tree oil provides unique set of terpens that disrupt cell membrane, inhibit sporulation and spore germination, iron transport, respiration and mycelial growth. TTO also fight against bacterial pathogens by inhibiting the infection process. So the hybrid fungicide can be effectively used as strategic approach in fungicide resistance management in orchards.

Protected cultivation

Protected cultivation is very promising in combating the problems due to climate change. Low tunnel technology was adopted by farmers of the Jaipur district of Rajasthan as protected cultivation. Under this technology, the *Cucurbitaceous* vegetables are grown inside the low tunnels during winter, creating congenial weather conditions and preventing the crops from frost injury and aphid infestation. The incidence of Cucumber Mosaic Virus (CMV) was very low in low tunnels in comparison to open field cultivation and the yield of cucurbitaceous vegetables grown in low tunnels was significantly superior to the open field cultivation[14]. Low tunnel systems allow for increased environmental control and improved marketable fruit yield and quality compared with the open-field plots of strawberries[15].

Plant disease forecasting models

Plant disease forecasting is the predicting the occurrence of plant disease in a specific area ahead of time, so that's suitable control measures can be taken in advanced to avoid further losses. EPIDEM for potato early blight, EPIMAY for Southern lip light of maize, EPIVEN for apple scab, BLIGHT CAST for late blight of potato, MARY BLIGHT for fire blight of Apple are example of computer simulation models, used for forecasting of plant disease epidemics[16]. Late blight of potato was successfully forecasted using the model JHULSACAST in Punjab Uttarakhand and west Bengal [17,18].

Nanotechnology in plant disease management

Nanotechnology is the study of synthesis and application of biomaterials of 1 to 100 nm in size. Nanoparticles are synthesized by three different ways i.e. physical, chemical and biological methods. Biological methods are more popular these days. Plant based synthesis is safe and fast and also works under room temperature without need of high physical condition Chemical nanoparticles such as copper nanoparticles commonly used to control fungal diseases of apple, Nano copper highly effective in controlling bacterial spot[19]. Zinc nanoparticles effective against *P. aeruginosa* and *Staphylococcus aeureus*. Silver nanoparticles applied vastly in treating unicellular microorganisms[20]. Nano particles are effective, cheap and ecofriendly in combating microbes[21].

Deep learning based rapid disease diagnosis

Quick and accurate diagnosis of plant disease is an important aid in the early treatment of disease & significantly decreases economic losses. Deep learning is machine learning approach which trains computers to do what people do instinctively i.e. learn by doing developed a deep learning based method to detect disease and pest in tomato.[22] Their findings show that the suggested system can effectively distinguish nine distinct kinds of disease and pest. The use of smartphone rising worldwide, advances in computer technology and advances in deep learning have opened the path for smart phone aided detection of plant disease[23]. Agrio precision Agriculture, Plantix, Crop doctor are some commonly used deep learning based mobile applications available for disease detection.

RNA interference (RNAi) mediated gene silencing

Gene silencing is the regulation of expression of genes in a cell to inhibit the expression of specific gene. The RNAi method includes the homology dependent silencing of genes which responsible to cause infection in a host plant before translation which is also called as post transcriptional gene silencing (PTGS). RNAi gene silencing is now popular for controlling the viral diseases[24]. The disease resistance in RNAi plants is associated with increase expression PR (pathogenesis related genes, PAL (Phenylamine Ammonia Lysis) & other genes encoding phytoalexin biosynthetic enzymes[25]. Susceptibility of powdery mildew in grapevine reduced through knock down of MLO (Mildew Locuso) genes by using RNAi mediated gene silencing[26]. Tomato leaf curl disease resistance is conferred by the expression of artificial microRNAs (ami RNAs) targeting the ATP binding domain of AC1 in transgenic tomatoes without affecting tomato yield[27]. Interference with viral βC1 ORF confers resistance to Yellow Vein Mosaic Virus (YVMV) in transgenic Okra [28].

Conclusion.

The rapid advancements in plant disease management reflect a critical shift toward more sustainable, precise, and integrated approaches to safeguarding global agriculture. From molecular diagnostics and remote sensing to biocontrol agents and genome editing technologies, each innovation plays a vital role in improving the speed, accuracy, and effectiveness of disease detection and control. Integrating these advanced techniques into existing management frameworks not only enhances crop productivity and resilience but also reduces dependence on conventional chemical controls, contributing to environmental and human health.

However, the successful implementation of these technologies requires concerted efforts in research, farmer education, policy development, and infrastructure support. Interdisciplinary collaboration and data-driven decision-making will be essential in translating these scientific breakthroughs into practical, field-ready solutions. As plant pathogens continue to evolve and climate change introduces new challenges, continued investment in innovation and adaptive management strategies will be indispensable in ensuring global food security and sustainable agriculture.

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References:

1. Reddy, C. A., Oraon, S., Bharti, S. D., Yadav, A. K. and Hazarika S. (2023). Advancing disease management in agriculture: A review of Plant Pathology Techniques. *Pl. Sci. Archives, 9*(11): 16-18.
2. Kavita, K., Saikanth, K. R., Pamala, P. Y., Kumar, P., Pandey, S. K., and Triyugi, N. K. (2023). Role of modern technologies in plant disease management: A comprehensive review of benefits, challenges and future perspectives. *Int. J. env. and climate changes,* 13 (12):1325-1335.
3. Mahlein A., Rumpf T., Welke P., Dehne H., Plümer L., Steiner U., Oerke E. 2013. Development of spectral indices for detecting and identifying plant diseases. *Remote Sensing of Env.,* 128: 21-30.
4. Buja, I., Sabella, E., Monteduro, A. G., Chiriaco, M. S., Bellis, L. and Luvisi, A. (2021). Advance in plant disease detection and monetary from traditional essay to in field diagnostic. *Sensors,* 21(6): 2129.
5. Hahn, F. (2009). Actual pathogen detection. *Sensors and Algorithms*, 2: 301-338.
6. Sankaran, S., Mishra, A., Ehsani, R., and Davis, C. (2010). A review of advanced techniques for detecting plant diseases. A review of advanced techniques for detecting plant diseases. *Computers and Ele. Agri.,* 72 (1): 1-13.
7. Zhang, S., and Wang, B. (2019). Plant disease detection and classification by deep learning - a review. *IEEE Access*, 9: 56683–56698.

8. Ngie, A., Abutaleb, K., Ahmed, F., Darwish, A., and Ahmed, M. (2014). Assessment of urban heat island using satellite remotely sensed imagery: a review. *South African Geographical J.,* 96 (2): 198-214.

9. Leeuw, D. J., Vrieling, A., Shee, A., Atzberger, C., Hadgu, K. M., Biradar, C.M., Keah, H., Turvey, C. (2014). The potential and uptake of remote sensing in insurance: a review. *Remote Sensing*, 6: 10888-10912.

10. Zhang, N., Yang, G., Pan, Y., Yang, X., Chen, L. and Zhao, C. (2020). Review of advanced technology and development for hyper spectral based plant disease detection in the past three decade's remote sensing.12 (19): 3188.

11. Suborna Rani, Kallol Das, Aminuzzaman, F. M. and Benjamin, Y. A. (2023). Harnessing the future: cutting-edge technologies for plant disease control. *J. Plant Protection Res.,* 63(4): 387-398.

12. Wang, F., Wang, C., Liu, P., Lei, C., Hao, W., Gao, Y., Liu, Y. G. and Zhao, K. (2016). Enhanced rice blast resistance by CRISPR/Cas9-targeted mutagenesis of the ERF transcription factor gene OsERF922. *Plos One,* 11(4): 947-952.

13. Reuveni, M., Gur, L., Henriquez, J. L., Frank, J., Tedford, E., Cloud, G. and Adaskaveg J. E. (2022). A new highly effective hybrid fungicide containing difenoconazole and tea tree oil for managing scab of apple, pecan and almond trees and as a tool in resistance management. *Plant Pathol.,* 71: 1774-1783.

14. Gangwar, R. K., Rathore, S. S., Gupta, N. K. and Sharma, R. K. (2015). Impact of protective cultivation on the yield and incidence of cucumber mosaic virus in cucurbitaceous vegetables. *Agriways,* 3(2):112-119.

15. Anderson, H. C., Rogers, M. A. and Hoover, E. E. (2019). Low tunnel covering and microclimate, fruit yield, and quality in an organic strawberry production system. *Horttechnology,* 29(5): 590-598.

16. Singh, B. P., Ahmad, I., Sharma, V. C. and Shekhawat, G. S. (2000). JHULSACAT: a computerised forecast a potato late blight in western Uttar Pradesh. *J. Indian potato Assoc.* 27 (1-2): 25-34.

17. Arora, R. K., Ahmad, I. and Singh, B. P. (2012). Forecasting late blight of potato in Punjab using JHULSACAST model. *Potato J.,* 39 (2): 173-176.

18. Chakraborty, A., Singh B. P., Islam A. and S. Sanjeev (2015). Forecasting late blight of potato in plants of West Bengal JHULSACAST model. *Potato J.,* 42(1):52-57.

19. Cheng, G., Dai, M., Ahmed, H. H., Wang, X. and Yuan, Z. (2016). Antimicrobial drugs in fighting against antimicrobial resistance. *Front microbiol,* 7: 470.

20. Kim, T. N., Feng, Q. L., Kim, J. O., Wu, J., Wang, H., Chen, G. and Cui, F. Z., (1998). Antimicrobial effects of mental ions (Ag +Cu2 + Zn2) in Hydroxyapatite. *Journal of material science: Materials in medicine,* 9(3): 129-134.

21. Saripalli, P. and Chippada, S. A. (2022). *J. of advance scientific research,* :13 (10): 1-6.

22. Fuentes, A., Yoon, S., Kim, S. C. and Spark, D. (2017). A robust deep learning based detection for real time tomato plant disease and pest recognition. *Sensors,* 17 (9): 1-21.

23. Mohanly, S. P., Hughes, D. P., and Salathe, M. (2016). Deep learning for image based plant disease detection front. *Pl. sci.,* 7:1-10.

24. Senthilraja, N., Gangwar, R. K. and Borad, C. K. (2024). Challenges and opportunities in Plant Disease Management: A Brief Review. *Madras Agri. J.,* 111: 1-7.

25. Liu, D., Chen, X., Liu, J., Ye, J. and Z. Guo. (2012). The rice ERF transcription factor OsERF922 negatively regulates resistance to Magnaporthe oryzae and salt tolerance. *J. Exp. Bot*., 63(10): 3899–3911.

26. Pessina, S., Lenzi, L., Perazzolli, M., Campa, M., Costa L. D., Urso, S., Vale, G., Salamini, F., Velasco, R. and M. Malnoy.(2016). Knockdown of MLO genes reduces susceptibility to powdery mildew in grapevine. *Hortic. Res*., 3: 1-9.

27. Sharma, N. and Prasad, M. (2020). Silencing AC1 of Tomato leaf curl virus using artificial micro RNA confers resistance to leaf curl disease in transgenic tomato. *Plant Cell Rep.,* 39: 1565–1579.

28. Ganesh, K.V., Mathew, D., Augustine, R., Soni, K. B., Alex, S., Shylaja, M. R. and Cherian, A. (2022). Development of transgenic okra (Abelmoschus esculentus L. Moench) lines having RNAmediated resistance to Yellow vein mosaic virus (Geminiviridae). *J. Virol. Methods*, 301:1-7.