Scientific Innovation Magazine
ISSN : 2584-1157

Innovative Tools for Diagnosing and Managing Plant Diseases

Monika Meena[1], Manisha Meena[2]
[1]Ph.D. Research Scholar, Department of Plant Pathology, Sri Karan Narendra Agriculture University Jobner, Jaipur, Rajasthan.
[2]Ph.D. Research Scholar, Department of Agriculture Chemistry and Soil Science , Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan.

Abstract

Pest and diseases pose a significant threat to the production of crops thus impacting the world's food security, ordinary plant disease diagnosis has its disadvantages in that they are sometimes lacking in the accuracy, speed and the number of samples they can handle. Recent advancements in medicines diagnostics have shifted the way that plant ailments are diagnosed, watched, and prevented. The current available tools, including molecular diagnosis, remote sensing, artificial intelligence, and biosensors, which are reviewed in this article are enhancing modern day plant diseases management. Techniques such as PCR and LAMP magnify the pathogen's genetic material making it easy to identify early pathogens. Drones and satellite imagery are useful techniques for identifying large-scale distal disease indicators because they can detect disease signs before outward manifestations become apparent. Diagnostic data is the area where the AI and ML models are being used for identifying the diseases that are precise and help in modeling the real time data for controlling the growth or chances of spread of plant diseases. Accompanying those advancements, biosensors and nanotechnology have become practical assets on field, fast pathogen identification improving early response prospects. These diagnostic instruments are alongside management practices including the Decision Support Systems (DSS) and mobile Apps for timely and right decisions for disease control. Despite these efforts, there are still three concerns; cost and availability of these technologies and the requirement of skilled personnel to perform the same. As the next steps, the further development of new diagnostic approaches, as well as intersectoral and interdisciplinary disease management concepts, and sustained research partnerships will be crucial. The present article offers a review of these

innovative tools, their uses, and the prospective advancement focusing on managing plant diseases, and formulate possible solutions for combating the emerging trends as evidenced by plant pathogens and climate change.

Introduction

Diseases parasiting plants remain one of the greatest threats facing agriculture the world over concerning its yields, quality and security. Consequently, the conventional methods of diagnostics were based on the identification of symptoms on the plant and the sample culturing, which are economically and time consuming in nature, and may not be accurate. When farming is done on larger land, to feed a growing number of people, time, as well as an efficient and quick diagnostic tool is areas that are very necessary. Fortunately, due to the progress in the advancement of technology, the diagnosis and combating of plant diseases is slowly receiving a new face as new technologies light the way in diagnosing, monitoring and containing plant diseases. Other inclusive and sophisticated forms of approaches include molecular diagnostics, remote sensing, artificial intelligence, and biosensors as critical tools in early disease diagnosis, identification of pathogens, and detection of disease development. These technologies therefore open up a pack where the health of the plants can be well understood such that treatments can be done to minimize on the disease outbreaks hence reducing major losses on crops. PCR, LAMP …This method can detect the pathogens at the molecular level causing the disease before development of clinical symptoms. Physical methods such as use of drones and satellite to control epidemic at large scale since they are able to detect patchy infected crops from a distance. Furthermore, deep learning with artificial intelligence and machine learning algorithms are complementing diagnostic possibilities by assessing big data from multiple origins and providing real-time recommendations in disease treatment. These tools are supported by biosensors and nanotechnology that facilitate quick identification of plant pathogens in the field, which will be of immense value for farmers in far reaching regions.

Categorization of traditional diagnostic methods

Conventional techniques for disease diagnosis in plants have been the starting point for disease identification and control in crop production. Many of these methods entail simple observation of the affected body parts or symptoms and micromanual techniques, and mostly involve extensive time and experience. However, these techniques have their challenges that restrict effective and efficient diagnosis of plant diseases in large scale production systems. Visual assessment is the simplest and the most frequently used method of monitoring plant diseases. It is about detection of signs which are marks on the leaves, wilting and yellowing of leaves as a sign of pathogen's presence. However, this method even leads to a misidentification as many of the diseases superficially show aforementioned symptoms and some of the pathogens occur as endophytes and cause subclinical infections. Furthermore, inspection may only reveal those diseases which are in advance stage and that reduce the chances of early diagnosis and prevention of spread of such diseases. Culturing is another old-fashioned strategy that can be used for the identification of pathogens. In this process, infected plant tissue samples are first grown on nutrient media as a way of developing the pathogen and identification of the pathogen itself is made on the basis of their gross morphology. Though useful in many cases, this method is slow taking days or even weeks for the pathogen to grow and be identified. Moreover, it can be useful only in case of dealing with such pathogens as viruses or fastidious bacteria, which cannot be effectively grown on culture media. Other methods of identification of plant pathogens include serological methods where enzyme-linked immunosorbent assay (ELISA) has also been used in the identification of the pathogens. These methods use the principle of antigens- antibodies interaction to map out specific pathogens in plant tissues. Even more specific than inspection by CCTV cameras are serological techniques which however have some drawbacks in sensitivity and in that they require special equipment and skills. However, these traditional approaches have rarely proven adequate for the current challenges including new pathogens, weather changes, and other factors which compel faster, reliable and large-scale disease diagnostics. Thus, modem diagnostic technologies are being elaborated to advance or supplant conventional methods, which are more appropriate in terms of accuracy and time.

Molecular Diagnostic Technique

Molecular diagnostic assays have made great strides in plant pathology by providing very high sensitivity, specificity, and most importantly the capacity to detect pathogens at the molecular level. These techniques surpass conventional practices, where infections are diagnosed early that is before symptoms are manifested and accurate diagnosis of plant pathogens therefore becomes easier. Out of all the molecular diagnostic methods, the most common method is the Polymerase Chain Reaction (PCR). PCR increases target gene copies of pathogens to a point at which they can be easily identified even if they exist in small numbers. This technique is very specific and cannot differentiate between fungi, bacteria, viruses and nematodes pathogenically. PCR can be designed to isolate certain genes or markers within a pathogen that would be exclusive to that pathogen thereby diminishing the likelihood of having a wrong result. Despite this PCR is somewhat more complex and is carried out with specific equipment and persons well trained to work on them hence not widespread in the developing nations. Another molecular technique is the Loop-mediated Isothermal Amplification (LAMP). Like PCR, LAMP amplifies DNA but again, there is a difference because LAMP works under a single temperature making it not possible to have a thermal cycler. This makes LAMP more portable and IB easier and suitable for use in the field diagnosis. LAMP assays are rapid, and samples can be analysed and processed within an hour; it will also readily be operationalised in remote environments. However, the applications of LAMP may need to design of primers specific to the detected pathogen.

Some other molecular methods used in diagnosis in addition to PCR include real time PCR (qPCR), DNA sequencing techniques, LAMP, Microarray and; and so on due to increased sensitivity in pathogen identification. Sequencing is a complete method of finding out the whole genetic composition of pathogens used in identifying new or unrecognized diseases qPCR gives out numerical results hence can be used to check on pathogen load at a given time is important in checking disease progression. In general, molecular diagnostic tools are a reliable analytical method in plant disease control because they are fast, specific and sensitive in detecting the pathogens hence sustainable disease control.

Scientific Innovation Magazine
ISSN : 2584-1157

Technology of Remote Sensing and Imaging

Mainly the techniques of remote sensing and the imaging analysis played an important role in large scale monitoring and identification of plant diseases. These technologies allow for a remote sensing capability, whereby through aerial or satellite sensing the stress and disease indications on the plants are captured before the can be seen through a lens and this assists farmers and researchers to monitor the health of crops in large fields. These methods are a quick, cheap and convenient way to check the state of plants during those periods when live inspection is labor-intensive and time consuming due to large areas of plantations or extensive territories, for example, in agriculture. Satellite imagery is one of the most popular techniques of remote sensing and offers accurate, high spatial resolution imagery of agricultural lands. Remote sensors are found aboard satellites and have several sensors that capture information at multiple spectral bands which include visible and infrared radiation. This enables identification of the slightest changes in plant health that may put them on the danger of pathogen attack as seen in chlorophyll level variation, changes in plant leaf temperature and moisture content. For instance, NDVI which is an indication of the vigor of plants may be used to check on the health of the crops farmer has planted through reflecting the amount of light that the crops reflect. Stress or disease brings a lower near-infrared reflectance value and targeted a give out allow initial recognition of possible infection.

Similar multispectral or hyperspectral sensors installed on unmanned aerial vehicles UAVs are becoming more routinely employed in more focused high spatial resolution surveillance measurements. Aerial photography by drones can be done at very low altitudes, allowing much more focus to be placed on a single plant or a part of the field rather than the entire field as would be done by satellites. They can also provide near-efficient area coverage depending on what is required thus they are efficient in disease control and early prevention. Also, thermal imaging can reveal changes in the temperature of the plants due to disease, drought stress or water logging. Other symptoms followed by the plant can easily be detected using thermal infrared sensors since the plant's temperature increases or decreases depending on the virus.

Roles of AI and Machine learning in identification of diseases

Plant Disease Diagnosis is benefiting from AI and ML as new Approaches for Early Detection and Identification of Diseases and Modelling. These technologies utilize big data to analyze large data sets and provide determinations that enhance disease control based on speed, accuracy and efficiency in large scale agricultural systems. Computer vision and deep learning such as AI and ML are also useful when the platforms can be trained to identify symptoms of diseases in plants with pictures from cameras, drones or satellite imagery. By embracing deep learning approaches, like convolutional neural networks (CNNs), those systems can detect and describe plant diseases using the image's patterns and features. This helps to do away with inspection, a method that can be very tine consuming and full of human error. The general knowledge of these algorithms increases as the size of data increases and therefore they can pinpoint diseases to the earlier stages or even in different environments. This type of model can also be used to forecast epidemics based on past data, climatic factors and factors that affect pathogens formation. For example, supervised learning technique may help knowing when and where particular diseases are likely to happen and therefore define appropriate interventions. These predictions can be included into Decision Support Systems (DSS), helping the farmers to make decisions where, when and at what rate treat and which crop is most vulnerable. further, AI and ML's use as a tool for allocating resources in disease management is promoting the achievement of the best results. Hence the utilization of the actual as well as real-time data from the sensors, satellite imagery as well as field observation; AI systems can aid in focusing on regions in dire need for attention and so, optimizes the usage of pesticides or fungicides for instance – a more sustainable way.

BUT, Biosensing and nanotechnology tools for the identification of plant diseases

Biological sensors and nanotechnology are in the forefront in monitoring and diagnosis of plant diseases since they offer high sensitivity and specificity as well as offer real time on-site analysis. This has been effective in early detection of the pathogens which allow further reduction of destructive and costly methods of analyzing the health of the plants. Biosensors are analytical devices incorporating biological components (enzymes, antibodies or nucleic acids etc) to identify certain pathogens or disease markers. They function by transforming a biological interaction into a reading in the form of an electric, a light or chemical signal. In plant disease diagnostics, biosensors are developed to indicate the presence of pathogen or pathogenic agent such as bacteria, fungi, viruses or nematodes based on molecular signatures. These sensors can be incorporated in portable equipment for HAZMAT identification on site analyses because time is always of essence in field work. Nano-biosensors appear to hold much potential since the unique properties of nanomaterials can dramatically improve the performance of diagnostic kits. Gold or silver nanoparticles can be used because they can be made selective for pathogen molecules by functionalizing it with receptors such as antibodies or DNA probes. The occurrence of the target pathogen species results in a change of the properties of the nanoparticles, which can be quantified. This makes it possible to detect even as low levels of the disease causing pathogens which can help time when they are not visible clinically. In addition, nanomaterials assist in enhancing the stability and the rate of biosensors that are ideal for use in real time monitoring. Nanotechnology is also involved in the creation of nanosensors to identify proper condition for disease vector breeding, such as humidity, temperature and pH of the soil. These sensors can be of immense help in provision of data that could be useful in early identification of disease risks and likely interventions. Both biosensors and nanotechnology constitute modern tools for effective, accurate, and inexpensive plant disease diagnostics. These innovations should greatly improve crop protection and make it easier to monitor diseases that could significantly threaten the food supply.

Integrated Disease Management Tools

Integrated Disease Management (IDM) therefore encompasses a subset of disease diagnostic, disease prevention and disease control tools for sustainable disease management of plants. Biological, chemical, cultural and mechanical methods are combined and integrated into IDM tools as the approach seek to use as less control methods as possible on plant diseases. Integration of DM into the business environment requires that early detection forms a fundamental part of IDM. New technologies of molecular diagnostics, remote sensing, and imaging help to diagnose diseases fast and consider the scope of their impact. The symptoms are clearly visible during the early stages when possible preventions to pathogen spread and crop losses are considerable. PCR and qPCR and DNA sequencing for example allow identification of pathogens at the molecular level that even before clinical signs of the diseases are evident. However, biological control agents are the most important component of IDM apart from diagnostic tools. These include useful microorganisms, for example bacteria, fungi, nematodes that are known to interfere with plant diseases. For example, Trichoderma and Bacillus are biocontrol agents that are used by spraying on the soil or plants to deprive or suppress with noxious pathogens as part of controlling the use of chemical pesticides in farming. Just like other elements of IDM, biological control supports other measures to improve on disease prevention and crop health.

Cultural practices also form an important aspect of IDM as discussed above and we now turn our attention to the next element. It is worth mentioning that the methods like crop rotation, right irrigation and watering practice, disease resistant varieties of crop and proper timing of pruning reflects a modified risk factor against diseases. In addition, technologies such as the soil sensors, and climate monitors used in precision agriculture, make these practices precise in their application. Chemical control is still used in IDM, but only in limited cases and only used when necessary avoiding the use of environmentally hazardous products such as chemical pesticides or using chemicals that are of a low toxicity. IDM guarantees that the chemical inputs are well applied in a precise way and in a way that will not affect the environment most.

Conclusion

Integrated Disease Management (IDM) is a broad relevant disease control strategy that targets plant diseases with an all-encompassing, sustainable, efficient, and effective approach. This is Integrated Management (IDM) strategy that utilizes a number of diagnostic tools, cultures, biocontrol agents and sometimes chemical control where necessary. The big advantage of using IDM is that it is a multifaceted approach, which can be effectively used in a particular disease environment, based on which methods will be most effective in order to reduce the effects of diseases and preserve the environment, as well as to improve the durability of crops. Early detection is a very crucial aspect of the implementation of the IDM strategy. High throughput methods and technologies such as molecular and remote sensing diagnose plant diseases early and provide accurate estimates of the disease situation to prevent further spread. It delivers many of these innovations right into the hands of farmers when they need them most: before diseases take an even bigger toll on crops and overall yield. Moreover, utilization of biological control has amore number of takers since they as targets are natural suppressors of pathogens from attacks, works as a safer option in comparison with chemical pesticides and are useful in integrated pest management 'IPM'.

Other practices which are still relevant include rotation, resistant variety, and cleaning up of fields. Precision agriculture tools add to the effectiveness of use of these practices as they improve the way they are implemented. Although a traditional chemical control is essential in some circumstances, its intentional, minimum application as part of IDM avoids damaging effects on crops, the environment or people.

References

- Anderson, T. E., & Bowen, C. R. (2019). Integrated disease management in modern agriculture: A framework for sustainable disease control. Journal of Agricultural Science, 57(4), 220-231.
- Bostock, R. M., & Cloyd, R. A. (2017). Sustainable pest management strategies in agriculture: A framework for integrated approaches. Pest Management Science, 73(2), 406-413.
- Choudhury, M. D., & Singh, R. P. (2018). Biological control and integrated disease management in crops. Crop Protection, 118, 133-139.
- Fenton, B. (2020). Advances in plant disease diagnostics: Tools and technologies for the integrated management of crop pathogens. Phytopathology, 110(8), 1360-1372.

- Ghorbani, R., & Seif, S. (2021). The role of integrated disease management strategies in reducing the impact of emerging plant diseases. Plant Disease Management, 35(5), 217-229.
- Hall, R., & Lee, M. (2018). Cultural control in integrated disease management of plant pathogens: A comprehensive review. Crop Protection, 110, 113-122.
- Jones, J. B., & Kuepper, G. L. (2019). Integrated pest and disease management: Principles and practices for sustainable agriculture. Sustainable Agriculture Reviews, 35, 139-159.
- Kessel, J., & Jones, S. (2020). Monitoring and surveillance in integrated disease management systems: Technologies and strategies. Plant Disease, 104(9), 1451-1461.
- Mazzola, M., & Schneider, M. (2017). Biological control agents for the management of soilborne plant diseases. Phytopathology, 107(2), 106-115.
- Pimentel, D., & Wilson, A. (2021). Ecological and economic benefits of integrated pest and disease management strategies in agriculture. Environmental Science & Policy, 120, 107-113.