An Analysis of Advanced Techniques for Detecting Plant Diseases

Dr. Santosh Kumar Singh, Assistant Professor

Department of Health & Allied Science, Arka Jain University, Jamshedpur, Jharkhand, India

Email Id-dr.santosh@arkajainuniversity.ac.in

ABSTRACT: Infections in plants generate significant productivity and economic losses in agricultural sector globally. Monitoring of health and identification of illnesses in plants and trees is important for sustainable agriculture. Towards the best of the knowledge, there's really no sensor commonly produced for real-time evaluation of health problems in trees. Nowadays, scouting is most frequently used method for measuring stress in trees, which is a costly, labor-intensive, and time-consuming procedure. Molecular methods also including polymerase chain reaction are utilized for the detection of plant diseases that need thorough sample and processing processes. Early knowledge on crop health and disease detection may assist the treatment of diseases via appropriate management methods such as vector control through pesticide applications, fungicide applications, and disease-specific chemical applications; and can increase production. The current study acknowledges the necessity for creating a fast, cost-effective, and reliable health monitoring sensor that would enable advances in agriculture. It covers the presently utilized technologies that may be used for creating a ground-based sensor system to help in monitoring health and illnesses in plants under field circumstances. Several methods encompass spectroscopic and image based, and volatile profiling-based plant disease detection techniques. The article examines the advantages and drawbacks of various possible approaches.

KEYWORDS: Advanced, Diseases, Detection, Health, Plant.

1. INTRODUCTION

Plant diseases generate significant productivity and economic losses in agriculture and forestry. For example, soybean rust has caused a major economic loss and simply by eliminating 20 percent of the infection, the farmers may gain with an approximately million-dollar profit. It is estimated that the agricultural losses due to plant diseases in United Stated result in approximately 33 billion dollars per year. Of this, approximately 65 percent may be ascribed to non-native plant pathogens. Some of the illnesses produced by imported pathogenic species include chestnut blight fungus, Dutch elm disease, and citrus disease. The bacterial, fungal, and viral infections, coupled with infestations by insects result in plant illnesses and damage. Upon infection, a plant develops symptoms that occur on various sections of the plants having a major agronomic effect. Many such microbial illnesses over time spread over a wider region in groves and plantations via unintentional introduction of vectors or through contaminated plant components. Another avenue for the transmission of diseases is via ornamental plants that serve as hosts[1].

These plants are often marketed via mass distribution before the diseases are recognized. An early disease detection system may help in reducing such losses caused by plant illnesses and can further limit the spread of infections. After the development of plant disease symptoms, the existence of illness in plants is confirmed using disease detection methods. Presently, the plant disease detection methods accessible include enzyme-linked immunosorbent assay, based on proteins generated by the pathogen, and polymerase chain reaction, based on particular deoxyribose nucleic acid sequences of the pathogen. In spite of availability of these methods, there is a need for a quick, sensitive, and selective method for the rapid diagnosis of plant diseases. Disease detection strategies may be generally divided into direct and indirect approaches. Figure 1 highlights some of these techniques of illness detection.

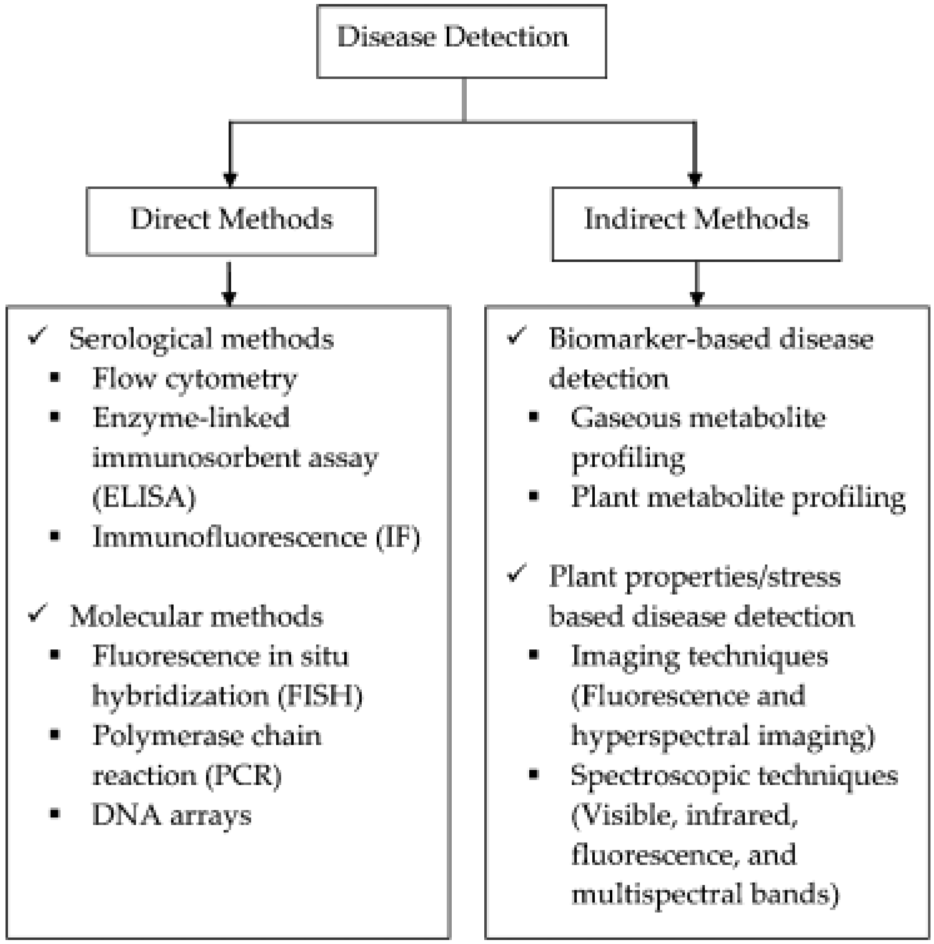

Figure 1: Illustrate the methods of plant disease detection technique can provide rapid, accurate, and reliable detection of plant diseases in early stages for economic, production, and agricultural benefits.

In the current article, innovative methods of ground-based disease detection that may be potentially combined with an autonomous agricultural vehicle are examined. In ground-based illness detection investigations, both field-based and laboratory-based experiments are addressed in this article. The field-based studies relate to studies that include spectral data gathering under field circumstances, while laboratory-based studies refer to data collection under laboratory conditions. The laboratory-based experiments offer solid baseline information for the field-based applications. This article discusses two methods used to identify plant diseases. The first method includes the use of spectroscopic and imaging techniques for illness diagnosis, while the second approach addresses the application of volatile organic molecules as potential biomarkers for disease detection. These two methods were chosen since they could be readily connected with an agricultural vehicle for a quick, reliable, and real-time plant disease monitoring for disease control and management. The early identification of plant illnesses may be a useful source of information for implementing appropriate pest management strategies and disease control methods to avoid the development and the spread of diseases.

1.1 Molecular approaches of detection of plant diseases:

Molecular methods of plant disease detection have been extensively established. The sensitivity of the molecular methods refers to the lowest quantity of microorganism that can be identified in the sample. The widely utilized molecular methods for disease detection include ELISA and PCR (PCR and real-time PCR) (PCR and real-time PCR). Other molecular methods include immunofluorescence (IF), flow cytometry, fluorescence in situ hybridization (FISH), and DNA microarrays[2]. In the ELISA-based disease detection, the microbial protein (antigen) linked with a plant disease is injected into an animal that develops antibodies against the antigen. These antibodies are collected from the animal's body and utilized for antigen identification using a fluorescent dye and enzymes. In presence of the disease-causing microbe (antigen), the sample would glow, thereby proving the existence of a specific plant disease. In PCR-based illness detection, the genetic material (DNA) of the disease-causing bacterium is collected, purified, and amplified before conducting the gel electrophoresis. The presence of a particular band in gel electrophoresis suggests the presence of the plant-disease causing bacterium. There are lot of research on illness detection utilizing the molecular methods. Efforts are underway to enhance the efficiency of these methods. Some of the drawbacks of the molecular methods include that they are time-consuming and labor-intensive, and need an extensive process, particularly during sample preparation to get trustworthy and accurate findings on plant disease diagnosis[3]. In addition, these methods need consumable chemicals that can only be customized to identify each particular pathogen (example sequence-specific primers for PCR) (e.g. sequence-specific primers for PCR). The molecular methods may be used as robust tool to test the presence of plant diseases, but cannot be utilized as a preliminary screening tool when analyzing multiple variety of plant samples owing to the time required in the process. Thus, spectroscopic methods may be promising approach for fast identification of plant diseases[4].

1.2 Spectroscopic and imaging methods for disease detection:

Significant advancements in agricultural technology have led to a need for a new age of automated non-destructive techniques of plant disease diagnosis. It is desired that the plant disease detection method should be fast, specific to a particular disease, and effective for identification at the early start of the symptoms. The spectroscopic and imaging techniques are distinctive disease monitoring approaches that have been used to identify illnesses and stress owing to different causes, in plants and trees. Ongoing research efforts aim towards the development of such technologies to produce a viable tool for a large-scale real-time disease monitoring during outdoor settings[5]. Various spectroscopic and imaging methods have been explored for the identification of symptomatic and asymptomatic plant diseases. Some the techniques are: fluorescence imaging, multispectral or hyperspectral imaging, infrared spectroscopy, fluorescence spectroscopy, visible/multiband spectroscopy, and nuclear magnetic resonance spectroscopy. The spectroscopic and imaging methods may be combined with an autonomous agricultural vehicle that can give information on disease detection at early stages to prevent the spread of plant diseases. This technique may also be used to detect stress levels and nutritional shortages in plants. In respect to plant disease detection, considerable study is underway on the potential of this technology from past several decades. Spectroscopic technology has already been effectively used for plant stress detection such as water-stress detection and nutrient-stress detection. In furthermore, there have even been major uses for evaluating the level of postharvest fruits and vegetables. Some of the frequently used spectroscopic and imaging methods are discussed in the following sections.

• *Fluorescence spectroscopy:*

Fluorescence spectroscopy refers to a kind of spectroscopic technique, where the fluorescence from the item of interest is measured following excitation with a beam of light (typically UV spectrum) (usually ultraviolet spectra). For the past twenty years, the laser-induced fluorescence has been utilized for vegetative research, such as to monitor stress levels and physiological states in plants[6].

Two kinds of fluorescence:

(a) blue-green fluorescence in approximately 400–600 nm range, and
(b) Chlorophyll fluorescence in approximately 650–800 nm range, are generated by green leaves. The fluorescence spectroscopy may be used to detect nutritional shortages, environmental factors based stress levels, and illnesses in plants

A portable fluorescence spectroscopy equipment was brought to the greenhouse and the measuring probe was positioned 2 mm above the leaf for gathering data from various samples throughout the duration of research (60 days). The spectral data were subsequently processed and evaluated in the laboratory. The samples of leaves taken from the field (detached leaves) as well as leaves from greenhouse plants were examined utilizing the system. The three ratios utilized were: ratio between fluorescence intensity at 452 and 685 nm, ratio between fluorescence intensity at 452 nm and 735 nm, and ratio between fluorescence intensity at 685 nm and 735 nm.

Fluorescence of citrus leaves was measured for 60 days under four distinct conditions: leaves with no stress, leaves with mechanical stress, leaves with disease, and leaves with disease plus mechanical stress. The investigations revealed the potential of fluorescence spectroscopy for illness diagnosis and differentiation between the mechanical and pathological stress. A similar technique was used to identify water stress and distinguish citrus canker leaves from variegated chlorosis leaves. The aforementioned investigations could differentiate healthy from citrus canker-affected leaves, but were unable to detect water stress and discriminate between variegated chlorosis and citrus canker-infected leaves[7].

- *Visible and infrared spectroscopy:*

Similar to fluorescence spectroscopy, visible and infrared spectroscopy have been utilized as a fast, non-destructive, and cost-effective technique for the diagnosis of plant diseases. It is a rapidly evolving technology utilized for various purposes. The visible and infrared portions of the electromagnetic spectra are known to give the greatest information on the physiological stress levels in the plants and therefore, certain of these wavebands unique to a disease may be utilized to identify plant illnesses, even before the symptoms are apparent. In general, visible spectroscopy is employed for disease detection in plants in conjunction with infrared spectroscopy evaluated the near infrared (NIR)-based method for detecting fire blight disease in the asymptomatic pear plants under greenhouse circumstances. The NIR method did not display potential for distinguishing infected plants from that of healthy ones, whereas electronic nose system showed a higher potential to categorize sick plants.

Monitoring of plant volatile organic molecules for disease detection:

The volatile organic compounds produced by plants and trees comprise approximately two-thirds of the total VOC emissions present in the atmosphere. There are number of variables that influence the volatile metabolic profile of a plant or tree. The VOCs produced by the plants rely on numerous physio-chemical variables such as humidity, temperature, light, soil condition, and fertilization, as well as biological factors such as growth and developmental stage of the plant, insects, and presence of other herbs. The physio-chemical variables either directly or indirectly influence the physiological state of the plant, thus affecting the VOC profile of the plant. These plant volatiles in turn affect their interaction between the plants and other creatures including diseases. For example, acetaldehyde is produced by the leaves of young poplar trees are regulated by the transfer of ethanol to leaves via transpiration examined a variety of plant volatiles generated by the plants owing to biotic and abiotic interactions. Some of the frequently observed secondary plant volatiles include terpenoids, volatile fatty acids, phenylpropanoids and benzenoids, and amino acid volatiles (such as aldehydes, alcohols, esters, acids, and nitrogen- and sulfur-containing volatiles produced from amino acids). The abiotic and biotic stressors may result in a change in the volatile profile of the plants that can be used for the plant disease detection the emphasis of the current study is towards the use of plant VOC profile monitoring for identifying illnesses in plants. The VOCs produced by the plants vary when the plant is afflicted with a disease owing to change in its physiology. These emissions are anticipated to differ from the VOCs produced under typical plant health circumstances. This technique may enable the identification of plant illnesses in real-time, thus avoiding the spread of plant diseases[8].

Sergio Cubero et al. studied the computer vision systems are becoming a scientific but also a commercial tool for food quality assessment. In the field, these systems can be used to predict yield, as well as for robotic harvesting or the early detection of potentially dangerous diseases. In postharvest handling, it is mostly used for the automated inspection of the external quality of the fruits and for sorting them into commercial categories at very high speed. More recently, the use of hyperspectral imaging is allowing the detection of not only defects in the skin of the fruits but also their association to certain diseases of particular importance. In the research works that use this technology, wavelengths that play a significant role in detecting some of these dangerous diseases are found, leading to the development of multispectral imaging systems that can be used in industry. It explains the different technologies available to acquire the images and their use for the non-destructive inspection of internal and external features of these fruits. Particular attention is paid to inspection for the early detection of some dangerous diseases like citrus canker, black spot, decay or citrus[9].

- *Electronic nose system:*

A computer vision based system consists of a set of gas sensors that are sensitive to a variety of organic chemicals. As each sensor has unique sensitivities, the sensitivities of a sequence of sensors may be utilized to distinguish various chemicals present in the environment. Electronic nose systems have been utilized for various purposes. They have been used to evaluate food quality, diagnose illnesses in people, and detect microbes in food items among others. The use of electronic nose systems for detecting plant diseases is relatively new area for its application. Blueberries were cleaned with ethanol to remove any naturally occurring fungus spores and germs. That once cherries were rinsed with deionized water to remove residual ethanol, they were subcultured with spore suspensions of three fungal species: *Botrytis cinerea, Colletotrichum gloeosporioides, and Alternaria spp*. that cause gray mold, anthracnose, and Alternaria fruit rot in postharvest blueberries, respectively. Principal component plots showed a strong demarcation between the control and berries with fungal infections. The berries with *C. gloeosporioides* could be clearly distinguished from the other groups, but there was considerable overlap in the VOC profiles of the berries infected with *B. cinerea and Alternaria spp*. The study effort mentioned above shows the possibility for using VOC profiling-based method for non-destructive plant identification[10].

2. DISCUSSION

Plants and trees produce volatile organic compounds as a consequence of the metabolic processes taking place inside its shoots, leaves, flowers, or fruits. The volatile profile of each plant varies considerably depending on its physiological state and the species. Various variables affect the profile of VOCs from a specific plant or tree, which may include changes in plant metabolism as a consequence of environmental changes, the age of plant, developmental stage of a plant, effect of stress on plants, and indeed the presence of disease/herbivore in a plant. One of the greatest difficulties in the use of plant gaseous metabolites as an indication for the presence of plant diseases is the natural diversity in the VOC profile within plant species. The fluctuation in VOCs produced by plants may conceal the changes owing to the stress and also the presence of illnesses. Therefore, there is a need to develop unique volatile biomarker specific for a particular plant and illness that would be different from the VOCs produced owing to an environmental or nutrient stress. For practical applications, development of a strong and reliable system for real-time monitoring of plant diseases is needed. It is possible to integrate the image and VOC profiling methods into an autonomous robot since these approaches are widely established for various industrial applications. Once these approaches are sufficiently established for a particular disease detection application, these technologies may be combined with an autonomous agricultural vehicle for authentic monitoring for plant diseases.

CONCLUSION

The current article examines and highlights some of the noninvasive methods that have been utilized for plant disease detection. The two main categories for non-invasive monitoring of plant illnesses are: I spectroscopic and imaging methods, and (ii) volatile organic components profiling-based methodology for identifying plant diseases. The spectroscopic and imaging methods include fluorescence spectroscopy, visible-IR spectroscopy, fluorescence imaging, and hyperspectral imaging. The VOC profile-based disease detection includes utilizing electronic nose or GC–MS based volatile metabolite analysis produced by healthy and sick plants as a technique for detecting illnesses. Some of the challenges in these techniques are: I the influence of supporting evidence in the resulting profile or data, (ii) optimization of both the technique for such a specific plant/tree and disease, and (iii) automation of the methodology for continuous automated surveillance of plant diseases under real - world situations field conditions. The study indicates that these techniques of disease detection exhibit a significant potential with a capacity to identify plant diseases correctly. The spectroscopic and imaging technology could be integrated with only an autonomous agricultural vehicle for reliable and real-time detection of plant diseases to achieve superior plant disease controllability.

REFERENCES:

[1] M. M. López, M. Roselló, and A. Palacio-Bielsa, “Diagnosis and detection of the main bacterial pathogens of stone fruit and almond,” *J. Plant Pathol.*, vol. 92, no. 1 SUPPL., 2010.

[2] V. Singh and A. K. Misra, “Detection of plant leaf diseases using image segmentation and soft computing techniques,” *Inf. Process. Agric.*, 2017.

[3] F. Martinelli *et al.*, “Advanced methods of plant disease detection. A review,” *Agronomy for Sustainable Development*. 2015.

[4] J. Belasque, M. C. G. Gasparoto, and L. G. Marcassa, “Detection of mechanical and disease stresses in citrus plants by fluorescence spectroscopy,” *Appl. Opt.*, vol. 47, no. 11, pp. 1922–1926, 2008.

[5] A. Y. Khaled, S. Abd Aziz, S. K. Bejo, N. M. Nawi, I. A. Seman, and D. I. Onwude, “Early detection of diseases in plant tissue using spectroscopy–applications and limitations,” *Applied Spectroscopy Reviews*. 2018.

[6] C. Zhang, X. Feng, J. Wang, F. Liu, Y. He, and W. Zhou, “Mid-infrared spectroscopy combined with chemometrics to detect Sclerotinia stem rot on oilseed rape (Brassica napus L.) leaves,” *Plant Methods*, 2017.

[7] H. Al Hiary, S. Bani Ahmad, M. Reyalat, M. Braik, and Z. ALRahamneh, “Fast and Accurate Detection and Classification of Plant Diseases,” *Int. J. Comput. Appl.*, 2011.

[8] S. Sankaran, A. Mishra, R. Ehsani, and C. Davis, “A review of advanced techniques for detecting plant diseases,” *Computers and Electronics in Agriculture*. 2010.

[9] S. Cubero, W. S. Lee, N. Aleixos, F. Albert, and J. Blasco, “Automated Systems Based on Machine Vision for Inspecting Citrus Fruits from the Field to Postharvest—a Review,” *Food Bioprocess Technol.*, vol. 9, no. 10, pp. 1623–1639, 2016.

[10] A. Berna, “Metal oxide sensors for electronic noses and their application to food analysis,” *Sensors*, vol. 10, no. 4, pp. 3882–3910, 2010.