

Early Detection and Identification of Red-Rot Disease in Sugarcane Leading Methods: A Review

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Abstract:

Introduction: Red rot is like a ‘cancer’ disease for sugarcane. Its detection can protect major losses in terms of production, economy, quantity and quality of sugarcane. Since red rot is a fungal disease, which mutilate the entire stalks and also spread to disease, so it’s considerably important to develop a correct and effective technique to detect the disease. In this paper we are presenting a review on various reasons of disease, its symptoms and various identification techniques. In first part of our paper, it is presented a review on disease impact on economy, quantity and quality loses, in second part it is presented various detection systems and in last the challenges of earlier detection.

Keywords: Sugarcane, Red rot, Disease detection, Biosensors, Fungal Disease.

1. Introduction

Saccharum spp. (Sugarcane) is an important cash crop cultivated in tropical and sub- tropical regions of the world. It is valuable mainly because of its ability to store high concentrations of sucrose, or sugar, in the stem and more recently for the production of ethanol, which is an important renewable bio-fuel source [1]. India is second world largest sugarcane producer and first consumer worldwide as per International Sugar Organization (ISO) report 2023.

As per Business and economic journals, India, 2023, Agriculture is the most important sector of Indian Economy. Indian agriculture sector accounts for 18 per cent of India's gross domestic product (GDP) and provides employment to 50% of the countries workforce. Sugarcane is a perennial crop which is composed of six species of perennial grasses of the genus Saccharum L. Production of sugarcane affected by many circumstances like- climate, soil, cultivation, biotic and abiotic stresses. It is reported that sugarcane is affected by approximately 240 types of diseases from plantation to harvesting [1]. Among 240, 55 types of diseases are caused by fungi, bacteria, viruses, phytoplasmas and nematodes in India. Sugarcane diseases are broadly classified into two groups, namely, sett-borne (red rot, smut, wilt, grassy shoot, ratoon stunting, leaf scald and mosaic) and non-sett- born (leaf spots, rust and root rots) [2, 3].

Among various biotic diseases, red rot is a fungal disease caused by *Colletotrichum Falcatum*. This fungal disease is exterminatory for sugarcane production in India. Red rot was first reported as a sugarcane disease by Went in Java in year 1893. It is a very old disease in sugarcane also.

Red rot causes poor stands of both plant and stubble crops as a result of the deterioration of the seed cuttings and the stubble rhizome; the destruction of seed cane in the storage beds (in the sirup-producing States); and the inversion of sucrose in mill cane, resulting in low recovery of sugar at the factory. The effect of gappy stands is felt not only in reduced tonnages of cane but also in the lower sucrose content of the juice resulting from the delayed maturity of the cane. Red rot affects both plant cane as well as stubble cane. In year 1923, a variety P.O.J. 213 was majorly being used in Louisiana United State, which had given a tremendous result in productivity and economy. This variety was being used up to 1934, in major areas of Louisiana but till 1934 after so many variations in productivity it was detected that due to red rot disease it became a major agricultural loss as well industrial loss. After that another variety P.O.J.-36-M was being used for some more years but still the red rot disease had lapped this variety also. The big effect of this scenario was to find a good variety of cane for heavy soil became a challenging task. Many reports had been declared that in addition to the losses due to reduced stand of cane, red rot also causes significant reductions in recoverable sugar at the factory because of the inversion of sucrose in the stalk. This phase of the subject was first investigated by Went, who found that the disease greatly lowered quality of mill cane [3, 5].

1.1 Losses:

It is unquestionable documented that approximately 10% of total area under sugarcane is destroyed by different pathogens. Sugarcane diseases hit formers on one hand and millers on other. Besides direct losses in terms of yields and juice quality, indirect losses, like (1) phrasing out of excellent commercial genotypes mainly due to sett-borne diseases is a major concern because every time we change a variety, we sacrifice a little either in yield or in juice quality, and (2) restriction on multiple ratooning in areas where it can't easily be practiced due to diseases. In India multiple ratooning is not in practice because of rapid buildup of pathogens [5].

1.2 Complexity of disease observation:

Red Rot pathogens can spread primarily by transmission through soil and diseased setts, while secondary transmission through air, rain splash and soil. In rainy season, the disease spread so fast that whole crop dries and not a single malleable cane is obtained. In the early stage of infection, it is difficult to recognize the presence of disease in the plant as the reddening of the internal tissues with interrupted red and white patches, the characteristic symptoms of the disease develop on the stem only at later stages. Furthermore, latent infection occurs frequently, making visual diagnosis impossible. First symptoms of the disease are seen when vegetative growth of the plant is stopped and sucrose formation begins i.e. after rainy season. Symptoms may not be readily apparent in the field, especially in the early stages of the disease. *C. Falcatum* can attack on any part of the sugarcane plant, be in stalk, leaf, buds or roots. *C. falcatum* completes its life cycle on the sugarcane leaf and usually the damage to the leaf does not pose a serious threat to cane or cause harm to plant. Discoloration of the leaves is the first symptom in the field. The spindle leaves (3rd and 4th leaf) display drying which withers away at the tips along the margins. Tiny reddish on upper surface of the lamina with minute red spot in both

direction of upper surface of the midrib appears. Leaves become straw coloured in the centre and dark reddish brown at the margins with the development of black acervuli. Infected leaves may break at the lesions and hang down [5].

Plants so affected may be detected by the yellowing, shriveling, and drying of the upper leaves. Drying up of margins can be seen at 3rd & 4th leaf from the crown. More certain identification of red rot can be made by splitting the stalk of standing cane. Splitting cane is a consummative method, which indirectly affect the ultimate production of crop. So, it's stringently required to develop an appropriate detection technique, which can give early disease detection facility to save crop from this epidemic [3, 5].

1.3 Prophylactic measures:

Possible ways to control red rot disease: -

1. Use of resistant variety
2. Treatment with fungicides such as carbendazim.
3. Biological control through antagonistic microorganisms [2,3,5].

1.4. Disease management:

Management of red rot disease in sugarcane has been a challenging area of work for the pathologist and sugarcane breeders. The factors of the epiphytotic of disease are required to be studied in depth. It is observed that once the disease has appeared in the field it is impossible to control. Most of the recommended management practices hence are aimed at prophylactic measures to reduce pathogen build up in the field [3]. Because of red rot pathogen diversity, a single method is not useful to extenuate the losses; hence Integrated Disease Management (IDM) practices are recommended [2]. Some of these practices are like: (1). Land selection, (2). Planting materials should be collected from nursery, (3). Sett treatment with BAU, (4). Following long furrow method or trace method for planting and irrigation, (5). Balanced fertilization, (6). Avoid ratooning, (7). Application of bavistin, (8). Use of red rot resistant varieties [2,3,5].

2. Literature Survey on Detection Techniques:

Various detection techniques are proposed by researchers. The detection methodologies and its categorically shown in fig.1.

1. Traditional Method [6,8,10]:
 - 1.1. Visual examination method:
 - Cheapest and earliest method.
 - Detection through visual symptoms like (spot, blight, galls, tumors, cankers, wilts, rots or damping- off).
 - Requires more detailed examination expertise because today's more detailed information is available.
 - 1.2. Culturing and planting:
 - Disease observation is based on morphological characteristics of pathogens.
 - Method is time consuming and requires more expertise.

- Suitable with other antibody and biochemical methods.
- 1.3. Isozyme analysis:
 - Isozyme is considered a precise, economical and rapid technique for classification and identification of pathogens.
- 2. Conventional methods:
 - 2.1. Advanced methods [6,8,10]:
 - 2.1.1. Direct detection technique:
 - This is laboratory-based technique, based on immunology, PCR and flow cytometry technique.
 - These methods provide faster detection and characterization than conventional methods, accurate characterization and differentiation of pathogens.
 - 2.1.2. Immunology based detection:
 - This is immunological reaction method.
 - This technique is not much specific and sensitive, but this is faster, more robust, simple to perform and cost effective.
 - 2.1.3. Polymerase Chain Reaction (PCR):
 - This is laboratory-based detection technique.
 - This technique is expensive, required laboratory setup, costly agents and skilled person.
 - Several types of PCR techniques are available [11].
 - 2.1.4. Flow Cytometry:
 - Laser based- optical technique
 - Rapid identification technique
 - Applied for cell cycle kinetics and antibiotic susceptibility
 - It is a new technique for plant disease detection.
 - 2.2. Indirect detection Methods:
 - Indirect methods are based on plant stress, gaseous metabolites and plant metabolites profiling.
 - Technique is based on impact of pathogens on plant response.
 - Depending on physiological properties this detection technique is mainly categorized as imaginary or spectroscopic technique and biomarker-based techniques.
 - 2.2.1. Imaginary Technique:
 - This technique is based on detection of change in wavelength of reflected light from plants.
 - A light of specific wavelength shoots on the tissues of plant and when it scattered its wavelength is changed. The changed wavelength gives an idea about the plant health.
 - Some of the detection techniques are: fluorescence spectroscopy, visible spectroscopy, infrared spectroscopy, nuclear magnetic resonance (NMR) spectroscopy, RGB imaging, fluorescence imaging, multispectral or hyper spectral imaging, X-Ray imaging, nuclear magnetic resonance (NMR) imaging, thermal imaging or thermography [9, 17].
 - 2.2.2. Volatile Organic Compound (VOCs) detection Technique:
 - Plants emit various volatile Organic Compounds in their surroundings, which is related to its physiological health status.
 - Crops that suffer from infestation emit VOCs indicate the damage in plant. This is early symptoms for farmers when plant stress comes due to microorganism or due to pests.

- Selection of a specific compounds for a specific infection in a plant is a critical issue in this technique, so it is required a fast, cheap and simple technique.

2.3. Biosensor based detection:

- This technique provides “on-site” detection facility.
- It provides a rapid detection for causal fungal pathogens.

2.3.1. Volatile sensor based:

- It's basically a gas sensor which detect gases released and can provide a real time indication for any fungal disease attacks. Various volatile sensors are available as well as under research.

2.3.2. Electronic Nose System:

- Electronic nose system is an electronic device which is used for “on-site” detection. It is used for early detection of pathogens in plant diseases. It is used for collecting information about chemical and physical properties of quality of plants. It consists two parts basically a sensors unit which sense or detect gases released from plants and second unit is a data processing (DSP/DIP) and analyzing unit which is used to process digital data for getting information about disease or conditions of plants. Today's in processing unit Machine Learning technique artificial neural networks (ANNs), KNN, AI, Adaboost, Baesian Network, Multilayer Perceptron, Random subspace, Bagging, Random forest and Extreme Gradient Boosting are mainly used. The gathered information is being matched with pre-stored fingerprints and analyze for a particular status. Sensors are actuators which are of many types for specific applications. It can be deployed a wireless sensor network (WSNs) in field for getting multiple types of information at the same time. Electronic nose system is mainly applicable for real time information [12, 13, 14, 15, 16, 18, 19, 20, 21, 22, 23, 24].

2.3.3. Field Asymmetric Ion Mobility spectrometry (FAIMS):

- FAIMS technology is based on gas/vapor's ion mobilization detection.
- Diseased plants emits gases/vapors when exist in stress caused by disease.
- Ions present in gas/vapor are passes in a chamber in presence of electric field, due to which ions accelerate and charged ions reached at cathode, as a result current at electrode vary which is measured and used as a marker for detection [9, 10].

2.3.4. Electrochemical biosensors:

- Electrochemical biosensor is a sensor-based detection technique which used chemical receptor to convert biomolecular bindings in electrical signals.
- This method is quite attractive for analysis of concentration of biological sample [9, 10].

2.3.4.1. Amperometric technique:

- This technique is generally based on current ampere measurement. Catalytically an enzyme system is converted into an active product on a electrochemical probe and measure current through probe.
- These biosensors are used as immunosensors or genosensors for detecting enzyme labelled traces.

2.3.4.2. Potentiometric technique:

- The enzyme-catalyzed reaction generates or consumes a species, which is detected by an ion-selective electrode. A high impedance voltmeter is used to measure the electrical potential difference or electromotive force (EMF) between two electrodes.

2.3.4.3. Impedimetric technique:

- In Electrochemical Impedance Spectroscopy (EIS) measurement a low amplitude sinusoidal signal is applied over a range of frequencies, and this causes changes in electrical impedance.

2.3.4.4. Conductometric techniques:

- By changing the ionic concentration, the change in conductivity can be measured in conductometric sensing techniques. It's a biosensor, which can detect the ionic concentration based on bio-recognition event.

2.3.5. Mass sensitive biosensor:

- Depending on change in mass of crystal of biosensor is determined to detect disease [9, 10].

2.3.5.1. Piezoelectric biosensors:

- Piezoelectric biosensors operate on the principle that a change in mass, resulting from the biomolecular interaction between two entities (e.g. an antibody and its respective antigenic determinant) can be determined.

2.3.5.2. Quartz crystal Microbalance Biosensors (QCM):

- A pathogen-specific antibody coated disc is used in this biosensor. When an oscillating electric field is applied across the disc, an acoustic wave with a certain resonance frequency is induced via a piezoelectric effect. The change in mass, which occurs when analyte accumulates on the surface of the disc, causes a change in resonance frequency. The resonance frequency change can then be directly proportional to biomolecular interactions.

2.3.6. Cantilever based biosensors:

Cantilever technology has been used in micro fabricated cantilever sensors functionalized with antibodies and is a promising new technique for biosensing applications.

2.3.7. Paper based diagnostic test:

- The reaction mechanism of these paper-based diagnostics can be categorized into chemical, biological and electro-chemical reactions.
- Paper-based diagnostic technologies are affordable, user-friendly, rapid, robust and economical for manufacturing, and thus provide an early diagnosis and guide the farmer's decision to deliver point-of-care (POC) diagnostics in resource-limited settings [10].

2.4. Optical biosensor:

- The main advantages of optical biosensors are selectivity, specificity, remote sensing, real time detection and compact design. This bio sensor works on the basis of change in phase, amplitude, frequency of the input light in response to physical or chemical change produced by bio-recognition process [10].

2.4.1. Fluorescence based biosensor:

- The intensity of the fluorescence indicates the presence of the target molecules and the interaction strength between target and bio-recognition molecules. Optical biosensors based on fluorescence detection use the combination of a fluorescent bio-receptor associated with an optical transducer.

2.4.2. Chemiluminescence based biosensor:

- It is a type of optical sensor whose monitoring is based on detection of rate of production of photon. The emerged light of immobilized biomolecules after reaction are measured with the help of photo multiplier tube (PMT).

2.4.3. Surface Plasma Resonance Sensor:

- This method is employed for real time detection techniques. The technique allows the measurement of a change in the effective refractive index on the surface.

2.5. Nanomaterial based biosensors:

- Using nanoparticles and nanostructures nanotechnology can be used as a fast and rapid detection of plant diseases. Nanoparticles and nanostructures facilitate a wide surface area for immobilized elements or by enhancing electronic and optical properties of materials [9, 10].

3. Conclusion on Challenges and Future Outlooks:

Plant pathogen detection techniques have been revolutionized in coming years due to quick, accurate, on-site and real time detection approaches. The sensor-based detection schemes can prove a significant improvement in this area because of rapid, accurate and real time on-site detection mechanism possibilities. Major challenges for these schemes are deployment of sensors on field. The sensor-based techniques integrated with various supporting systems such as data analysis approaches (for collected data by sensors) can encapsulate real time detection possibilities. Its application requires an expertise in instrumental data analysis and deployment procedures. Possibilities accentuate for more research on this area. Availabilities of nanotechnologies for fabrication of sensors can become new possibilities in this field. The major challenges, which arises for research are collection of datasets for efficiently classification and detection of diseased symptoms. There are a number of datasets that may be useful for researchers working on the identification and classification of plant leaf diseases. Some examples include:

PlantVillage dataset:

This dataset contains over 50,000 images of plant leaves, representing 38 different crop species and over 15 different diseases. It is one of the largest and most comprehensive datasets available for plant disease detection and classification.

LeafSnap dataset:

This dataset contains over 15,000 images of plant leaves, representing 185 different species. It was created for the development of a mobile app for plant identification, but may also be useful for researchers working on leaf disease detection and classification.

Plant Disease dataset:

This dataset contains over 4,000 images of plant leaves, representing 38 different crop species and 14 different diseases. It was created for the development of a plant disease detection and classification system.

Cassava Dataset:

There are 9,436 images labeled by agriculture experts with resolution of 4000×2672 . The Cassava dataset is obtained from the “Cassava leaf disease competition” on the Kaggle platform. Since the ground truth for the test dataset is not available, the training dataset is divided into training, validation, and test subsets, with sizes of 60%, 20%, and 20%, respectively.

Apple leaf dataset:

The Apple leaf dataset comprises multiple images of apple foliar diseases, which exhibit a range of lighting, angles, surfaces, and noise levels. These images are captured in real-world field conditions, using a Canon Rebel T5i DSLR and smartphones. The dataset covers total 3,651 RGB images with resolution of 1048×1365 pixels.

Notably, studies on the PlantVillage dataset, such as PS Thakur et al. (2022), M Adi et al. (2021), F Arshad et al. (2023), and A da Silva Abade et al. (2019), have demonstrated the efficacy of SVM, CNN, and Random Forest, with CNN consistently emerging as a robust choice, achieving remarkable accuracy rates. These collective results signify the ongoing evolution and success of machine learning and deep learning methodologies, particularly highlighting the pivotal role of CNN in the accurate classification of crop diseases.

In conclusion, Machine Learning and Deep Learning Methods for Efficiently Predicting and Classifying Crop Disease Data is an innovative area that offers a new approach to addressing the challenges of crop disease identification and management.

However, there is still more scope for future research in this area. One potential direction for future research is to investigate the generalizability of the proposed approach on a larger and more diverse set of datasets

Furthermore, research can also be conducted to optimize the computational efficiency of the approach, making it more practical and feasible for use in real-world agricultural scenarios. Additionally, incorporating explainable AI techniques could provide more transparency and interpretability to the classification and prediction results, which would be valuable for farmers and other stakeholders.

Overall, the proposed review presents an exciting opportunity to improve crop disease management using computational intelligence, and future research can continue to build upon this work to develop even more effective and efficient solutions.

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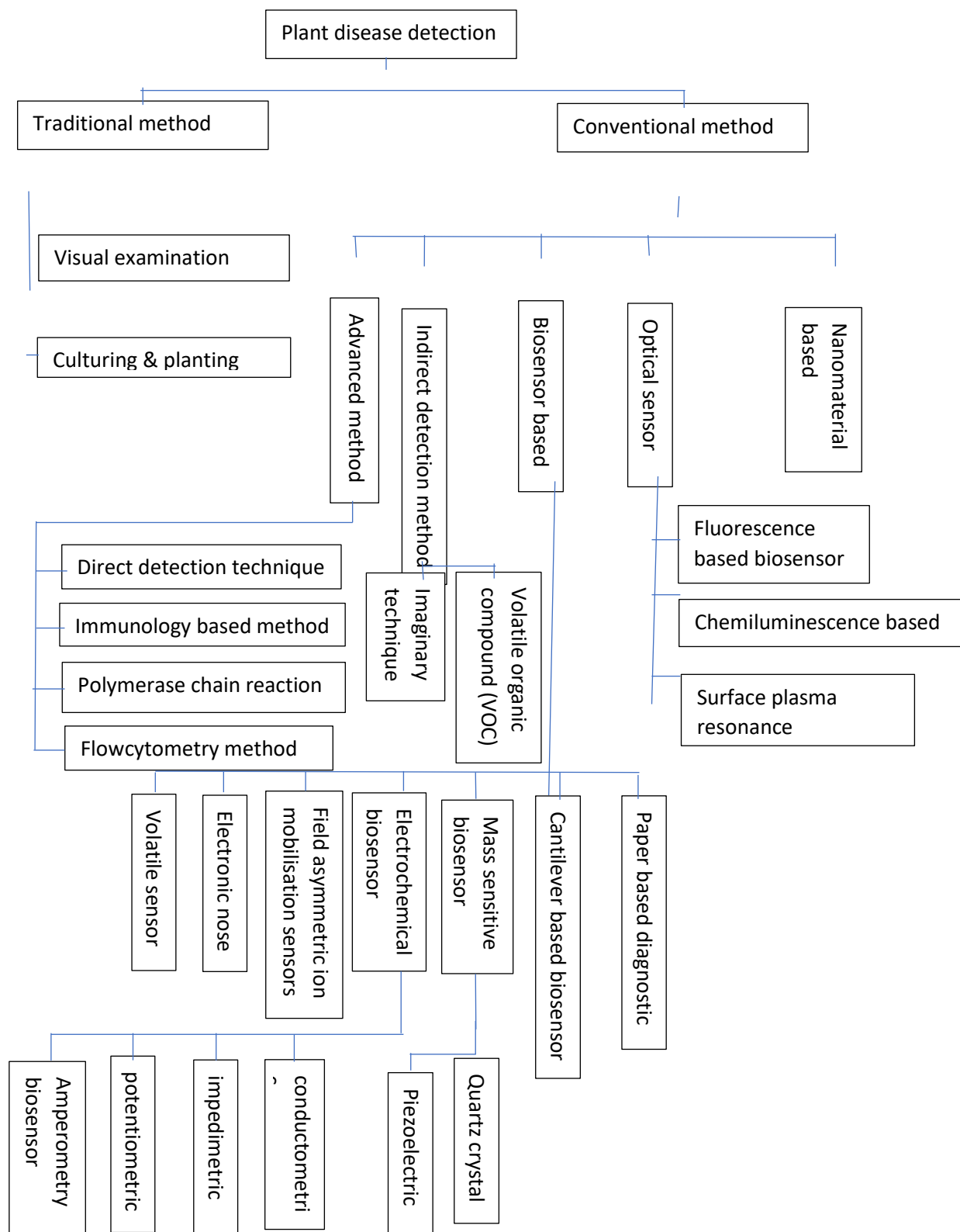


Fig. 1. Plant disease detection Techniques