
SUGARCANE DISEASE DETECTION USING MACHINE LEARNING: INDIAN AGRICULTURE

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ABSTRACT

Sugarcane is a vital commercial crop in India, playing a crucial role in the agricultural economy and supporting the sugar industry. However, its productivity is significantly threatened by various diseases caused by fungi, bacteria, viruses, and pests. Major diseases such as red rot, leaf scald, smut, and rust can spread rapidly if not identified at an early stage, resulting in substantial yield reduction and economic losses for farmers. Conventional methods of disease detection, which rely on manual inspection, are time-consuming, labor-intensive, and inefficient for large-scale farming environments

This study presents an automated system for detecting sugarcane diseases using machine learning and image processing techniques.

The proposed system employs remote sensing data acquired through drones or high-resolution imaging devices to enable continuous monitoring of agricultural fields.

The methodology is divided into two primary stages. In the first stage, a dataset comprising images of healthy and diseased sugarcane leaves is collected and preprocessed. Preprocessing steps include image resizing, noise reduction, grayscale transformation, and normalization to improve image quality and consistency. Feature extraction is carried out using edge detection methods, particularly the Canny Edge Detection algorithm, along with histogram-based analysis to capture variations in color and texture associated with disease symptoms.

In the second stage, a machine learning model is trained to classify the leaf images into healthy or diseased categories. The model evaluates features such as leaf patterns,

discoloration, lesion characteristics, and irregular textures to detect infections at an early stage. Early identification of diseases, especially at the outer leaf layer, enables timely intervention and helps prevent large- scale crop damage.

The proposed approach offers a cost- effective, efficient, and scalable solution for modern agriculture. It facilitates real-time crop monitoring, reduces reliance on manual inspection, minimizes excessive pesticide usage, and enhances overall crop productivity. By integrating remote sensing with machine learning, this system contributes to sustainable agriculture and promotes precision farming practices.

KEYWORDS: Sugarcane Disease Detection, Machine Learning, Image Processing, Remote Sensing, Canny Edge Detection, Precision Agriculture.

INTRODUCTION

Agriculture has long been a cornerstone of human development and remains a primary contributor to the economy of developing countries such as India. A substantial share of the population depends on agriculture either directly or indirectly for their livelihood. With the continuous growth in population, the demand for food, sugar, and other agricultural commodities is increasing at a rapid pace. This situation makes it essential to adopt modern technologies and innovative practices in agriculture to enhance productivity, maintain food security, and support economic stability.

Among the major crops grown in India, sugarcane stands out as a highly valuable commercial crop. It is widely cultivated and serves as the main source for sugar production. In addition to sugar, sugarcane is utilized in the production of jaggery, ethanol, biofuels, and several other industrial products. India is recognized as one of the leading producers of sugarcane globally, and the crop plays a significant role in supporting the livelihoods of millions of farmers. It also contributes to employment generation in rural areas and supports various agro-based industries.

However, sugarcane cultivation is frequently challenged by a wide range of plant diseases caused by fungal, bacterial, viral, and pest- related factors. Common diseases such as red rot, smut, rust, mosaic, and leaf scald negatively impact plant health and productivity. These diseases primarily affect the leaves and stalks, leading to symptoms such as discoloration, lesion formation, spots, and irregular growth. Since leaves are essential for photosynthesis, any damage to them reduces the plant's ability to produce energy, thereby affecting growth and sugar yield. If these diseases are not identified in their early stages, they can spread

quickly across fields, causing severe losses in both crop quality and quantity.

Conventional disease detection techniques mainly rely on manual observation and expert judgment. Farmers typically identify diseases based on visible signs, which may result in incorrect diagnosis due to limited knowledge or experience. Furthermore, inspecting large agricultural fields manually is both time-consuming and labor-intensive.

Access to agricultural experts for proper diagnosis and treatment recommendations is also limited, especially for small-scale farmers. These challenges often lead to delayed detection, improper pesticide application, increased costs, and reduced efficiency.

To address these limitations, there is a strong need for an automated, reliable, and cost-effective disease detection system. Recent progress in machine learning, image processing, and remote sensing technologies has created new opportunities for improving agricultural practices. By using images of sugarcane leaves captured through cameras or drone-based systems, advanced algorithms can analyze visual features such as color differences, texture patterns, edge irregularities, and spot formations to detect disease symptoms accurately.

This research proposes an automated sugarcane disease detection system that integrates image processing techniques with machine learning models. The system is designed to function in two main stages. The first stage involves the training process, where images of both healthy and diseased leaves are collected, preprocessed, and used to train the model. The second stage focuses on the detection process, where techniques such as Canny Edge Detection and feature extraction are applied to classify leaf images into healthy or diseased categories.

Sugarcane Diseases

Sugarcane is one of the most important commercial crops cultivated across India and other tropical and subtropical regions. It plays a significant role in the agricultural economy and supports a wide range of agro-based industries. However, the productivity and quality of sugarcane are highly vulnerable to various plant diseases, which pose a major challenge to farmers.

These diseases are primarily caused by different biological agents, including fungi, bacteria, viruses, and pests. Their impact can be severe, especially when infections are not identified and managed at an early stage. Uncontrolled disease spread often results in reduced crop yield, lower sugar content, and considerable financial losses.

In sugarcane plants, disease symptoms are commonly observed on leaves, stems, and stalk tissues. Visible indicators may include discoloration, lesions, spots, streaks, and abnormal

growth patterns. Since leaves play a crucial role in photosynthesis, any damage to leaf tissues directly affects the plant's ability to produce energy, ultimately reducing overall crop productivity and sugar accumulation.

Early detection of these symptoms is essential for effective disease management. Timely identification allows farmers to take appropriate preventive and corrective measures, thereby minimizing crop damage and improving yield quality.

The major sugarcane diseases are discussed in the following sections:

Red Rot Disease of Sugarcane



Red Rot is considered one of the most severe and destructive diseases affecting sugarcane cultivation. Due to its aggressive nature and the extensive damage it causes, it is often referred to as the “*cancer of sugarcane*.” This disease has historically led to significant reductions in crop productivity, particularly in tropical and subtropical regions such as India, where sugarcane is widely cultivated.

Causal Organism

Red Rot is caused by the fungal pathogen *Colletotrichum falcatum*. This organism primarily targets the stalk (stem) of the sugarcane plant, although under severe conditions, it may also infect leaves and other plant tissues. The pathogen is highly persistent in nature, surviving in infected plant debris, soil, and diseased planting materials (seed sets), which makes its control and eradication challenging.

Symptoms of Red Rot Disease

The symptoms of Red Rot vary depending on the stage of infection and environmental conditions. These symptoms can be categorized into external and internal manifestations:

1. External Symptoms

- Yellowing and gradual drying of leaves, usually beginning from the upper portion.
- Drooping and wilting of leaf blades.

- Reduced plant vigor and overall stunted growth.
- Complete drying of the plant in advanced stages of infection.

2. Internal Symptoms (Key Diagnostic Feature)

- On splitting the infected cane longitudinally, the internal tissues exhibit a reddish discoloration.
- Distinct white patches or transverse streaks appear within the red tissues.
- A characteristic sour or alcoholic odor may be present.
- The internal pith becomes soft, spongy, and eventually decomposes.

The presence of alternating red and white patches inside the stalk is considered the most reliable diagnostic indicator of Red Rot infection.

Mode of Infection and Spread

The fungus enters and spreads through multiple pathways, including:

- Use of infected seed sets during planting.
- Entry through wounds caused by insects or mechanical damage.
- Soil-borne spores under favorable environmental conditions.

The disease spreads rapidly under conditions such as:

- Warm and humid climate
- Waterlogged fields
- Poor soil drainage

High temperature combined with excessive moisture creates an ideal environment for fungal growth and rapid multiplication.

Impact on Crop Yield and Quality

Red Rot significantly affects both the yield and quality of sugarcane. Its major impacts include:

- Reduction in cane weight
- Decline in sugar recovery percentage
- Deterioration of juice quality
- Complete crop loss in severe cases

If not controlled in time, the disease can spread across entire fields, leading to heavy financial

losses for farmers.

Economic Importance

In a country like India, where sugarcane farming supports millions of livelihoods and contributes to the sugar industry, Red Rot is a major concern. Since sugarcane is a long-duration crop (approximately 10–14 months), infection at any stage can result in substantial economic damage, making early detection and management essential.

Detection and Identification

Conventional detection methods rely on manual inspection and splitting of stalks to observe internal symptoms. However, early-stage detection is difficult using these traditional approaches.

With the advancement of technology, modern techniques such as image processing and machine learning are being utilized for early disease detection. These methods analyze digital images of sugarcane leaves and stalks using:

- Canny Edge Detection
- Color histogram analysis
- Texture feature extraction

Such techniques enable the identification of subtle changes in color, texture, and structure, allowing early diagnosis before the disease spreads extensively.

Rust Disease (Brown Rust) of Sugarcane



Rust disease, commonly referred to as Brown Rust, is one of the most prevalent fungal infections affecting sugarcane crops across tropical and subtropical regions. It primarily

targets the leaves, leading to a reduction in photosynthetic efficiency and overall plant health. In major sugarcane-producing countries such as India, outbreaks of rust disease have resulted in significant yield losses, particularly under favorable environmental conditions.

Causal Organism

Brown Rust is caused by the fungal pathogen *Puccinia melanocephala*. This organism is an obligate parasite, meaning it can only survive and reproduce on living plant tissues. The fungus mainly infects the leaves and spreads rapidly through airborne spores, making it highly transmissible across fields.

Symptoms of Rust Disease

The symptoms of Brown Rust appear predominantly on leaf surfaces and develop progressively over time:

1. Early Stage Symptoms

- Appearance of small, elongated yellow spots on the leaf surface.
- Gradual enlargement of spots, which turn reddish-brown in color.
- Mild yellowing (chlorosis) surrounding the infected areas.

2. Advanced Stage Symptoms

- Formation of numerous reddish-brown pustules on both sides of the leaf.
- Rupture of pustules, releasing fine, powdery spores.
- Development of dry and necrotic (dead) leaf tissues.
- Premature drying and shedding of leaves under severe infection.

The presence of reddish-brown powdery pustules is the most distinctive characteristic of Brown Rust disease.

Mode of Infection and Spread

The spread of the rust pathogen occurs mainly through:

- Airborne spores carried over long distances by wind.
- Moisture present on leaf surfaces, which facilitates spore germination.
- Favorable temperatures ranging between 20°C and 30°C.
- High humidity and cloudy weather conditions.

Once spores settle on a suitable host under moist conditions, they germinate and penetrate the leaf tissue, initiating infection.

Impact on Plant Growth and Yield

Rust disease significantly affects sugarcane productivity in multiple ways:

- Reduction in effective leaf area for photosynthesis.
- Decrease in chlorophyll content.
- Slower plant growth and development.
- Reduction in cane weight and sugar recovery.
- Overall decline in yield quality.

Under severe conditions, yield losses may range between 20% and 40%, depending on environmental factors and crop variety.

Economic Importance

Given the importance of sugarcane in sugar and ethanol production, rust disease poses a serious economic threat. Large-scale infections can lead to substantial financial losses for farmers. Additionally, increased expenditure on fungicides and crop management further raises production costs. Continuous infection weakens the plant, making it more susceptible to other diseases and environmental stresses.

Detection Using Image Processing

Traditional detection methods rely on visual inspection of leaves, which may not be effective for identifying early-stage symptoms in large fields.

Modern automated approaches utilize image processing and machine learning techniques, including:

- Canny Edge Detection for identifying lesion boundaries.
- Color histogram analysis to detect reddish-brown pigmentation.
- Texture feature extraction to analyze surface irregularities.
- Machine learning classifiers to distinguish between healthy and infected leaves.

These advanced techniques enable early and accurate detection, allowing timely intervention and better disease management.

Smut Disease of Sugarcane



Smut disease is a highly significant fungal disease that poses a serious threat to sugarcane cultivation. It adversely affects plant growth, reduces yield, and lowers sugar recovery. The disease is widely prevalent in tropical and subtropical regions, including India. If not effectively managed, smut infection can persist across multiple cropping cycles, leading to substantial long-term productivity losses.

Causal Organism

Smut disease is caused by the fungal pathogen *Sporisorium scitamineum*. This pathogen primarily infects the growing buds of the sugarcane plant. After infection, the fungus may remain dormant within plant tissues until favorable environmental conditions trigger its growth and development.

Symptoms of Smut Disease

The most distinctive feature of smut disease is the formation of a black, whip-like structure known as the “smut whip,” which emerges from the top of the infected plant.

1. Early Stage Symptoms

- Reduced tillering, resulting in fewer side shoots.
- Slight stunting of plant growth.
- Narrow, elongated leaves.
- Pale green coloration of foliage.

2. Advanced Stage Symptoms

- Emergence of a long, black whip-like structure from the growing point.

- The whip contains a large number of fungal spores.
- Development of thin, weak stalks with reduced thickness.
- Drying and degeneration of infected shoots.

The smut whip eventually ruptures, releasing spores into the air, which then infect nearby healthy plants.

Mode of Infection and Spread

The disease spreads through several pathways, including:

- Use of infected seed sets (planting material).
- Airborne dispersal of fungal spores.
- Contaminated agricultural tools and equipment.
- Presence of infected crop residues and soil.

The pathogen typically enters through the buds and establishes itself within plant tissues. Warm temperatures (25–35°C) combined with moderate humidity create favorable conditions for disease development.

Impact on Plant Growth and Yield

Smut disease significantly reduces crop performance in various ways:

- Decrease in cane thickness and plant height.
- Reduction in sugar content.
- Poor performance of ratoon crops (subsequent harvest cycles).
- Yield losses ranging from 10% to 50%, depending on infection severity.

Repeated infection over successive cropping cycles can severely affect overall farm productivity.

Economic Importance

As sugarcane is a long-duration crop and a key industrial raw material, smut disease can lead to major economic losses. Farmers may experience reduced crop value and increased expenses for disease management. Additionally, the disease affects the quality of planting material, increasing the risk of infection in future crops.

Detection Using Image Processing and Machine Learning

Traditional detection methods rely on visual identification of the black smut whip. However, early symptoms such as reduced tillering and narrow leaves are often difficult to detect manually.

Advanced detection systems utilize image processing and machine learning techniques, including:

- Canny Edge Detection to identify abnormal structures such as the smut whip.
- Color analysis to detect black pigmentation.
- Texture feature extraction to recognize structural abnormalities.
- Machine learning models to classify plants as healthy or infected.

These techniques enable early and accurate detection, helping to control disease spread and minimize crop losses.

Mosaic Disease of Sugarcane



Mosaic disease is a widely prevalent viral infection that significantly affects sugarcane cultivation. It is considered economically important due to its impact on plant growth, sugar accumulation, and overall yield. The disease is commonly observed in sugarcane- growing regions, including India and other tropical areas. Since it is caused by a virus, effective chemical treatment is not available, making prevention and early detection crucial for disease management.

Causal Agent

Mosaic disease is caused by the *Sugarcane Mosaic Virus (SCMV)*, which belongs to the

Potyvirus group. This virus primarily infects the leaf tissues of the sugarcane plant. Once a plant is infected, it cannot be cured, and the infection persists throughout its lifecycle.

Symptoms of Mosaic Disease

The symptoms of mosaic disease are mainly visible on the leaves and become more pronounced as the infection progresses.

1. Early Stage Symptoms

- Appearance of light green and dark green patches on leaves.
- Mild discoloration forming irregular patterns.
- Slight narrowing of leaves.

2. Advanced Stage Symptoms

- Formation of a distinct mosaic or mottled pattern with alternating light and dark green areas.
- Distorted and twisted leaf structure.
- Stunted plant growth and reduced vigor.
- Decrease in tiller formation.
- Reduced chlorophyll content in leaves.

The characteristic mosaic pattern on the leaves is the most reliable indicator of this disease.

Mode of Infection and Spread

The virus spreads through multiple pathways, including:

- Use of infected seed sets (vegetative planting material).
- Transmission by insect vectors such as aphids.
- Mechanical transmission through contaminated tools and handling.
- Direct contact between infected and healthy plants.

Environmental conditions such as warm temperatures and increased aphid activity accelerate the spread of the disease.

Impact on Plant Growth and Yield

Mosaic disease negatively affects sugarcane production in several ways:

- Reduction in photosynthetic efficiency.
- Decrease in cane thickness and plant vigor.
- Lower sugar accumulation in the stalk.

- Poor performance of ratoon crops.
- Yield losses ranging from approximately 15% to 35%.

Since sugarcane is propagated vegetatively, the use of infected planting material can lead to rapid and widespread transmission across fields.

Economic Importance

As sugarcane is a major raw material for sugar and ethanol industries, mosaic disease has direct economic implications. It reduces both yield and sugar recovery percentage, leading to decreased profitability for farmers. The spread of infection through planting material further increases long-term losses.

Detection Using Image Processing and Machine Learning

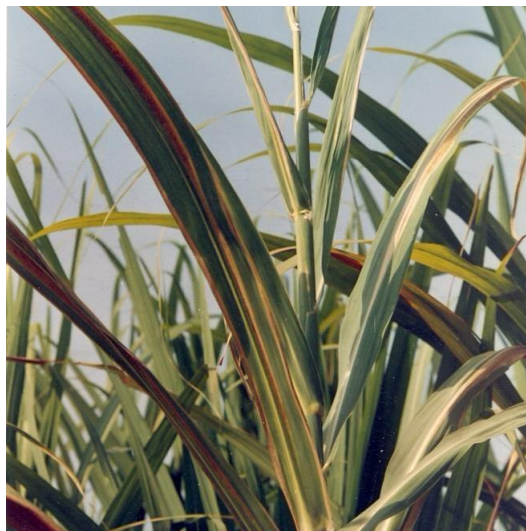
Although mosaic disease can be identified visually due to its distinct leaf patterns, early-stage symptoms may be subtle and difficult to detect in large agricultural fields.

Modern detection systems utilize advanced techniques such as:

- Color histogram analysis to identify variations in green shades.
- Texture analysis to detect irregular mosaic patterns.
- Canny Edge Detection to identify structural distortions in leaves.
- Machine learning algorithms to classify leaves as healthy or infected.

These approaches enable faster, more accurate, and large-scale disease detection compared to traditional manual inspection methods.

Leaf Scald Disease of Sugarcane



Leaf Scald is a significant bacterial disease that adversely affects sugarcane production by reducing both yield and juice quality. It is commonly observed in tropical and subtropical sugarcane-growing regions, including India. One of the major challenges associated with this disease is its latent nature, where symptoms may remain unnoticed for an extended period before becoming severe.

Causal Organism

Leaf Scald disease is caused by the bacterium *Xanthomonas albilineans*. This pathogen primarily infects the vascular tissues (xylem) of the plant, disrupting the transport of water and essential nutrients, which ultimately affects plant growth and development.

Symptoms of Leaf Scald Disease

The symptoms of this disease vary depending on environmental conditions and the variety of sugarcane, but they mainly appear on the leaves.

1. Early Stage Symptoms

- Appearance of thin white or yellowish streaks running parallel to the leaf veins.
- Mild chlorosis (yellowing) of leaves.
- Slight reduction in plant vigor.

2. Advanced Stage Symptoms

- Expansion and widening of white streaks across the leaf blade.
- Drying of leaf tips.
- Burnt or “scalded” appearance of leaves.
- Wilting and curling of foliage.
- In severe cases, complete drying of the plant (top rot).

The presence of linear white streaks along the veins is considered the most distinctive symptom of Leaf Scald disease.

Mode of Infection and Spread

The disease spreads through several pathways, including:

- Use of infected seed cane as planting material.
- Contaminated cutting tools and agricultural equipment.

- Rainwater splash and irrigation systems.
- Mechanical injuries during cultivation practices.

The bacteria enter the plant through natural openings or wounds and multiply within the vascular system. Warm temperatures and high humidity create favorable conditions for disease development.

Impact on Crop Yield and Quality

Leaf Scald disease negatively influences sugarcane production in multiple ways:

- Reduction in photosynthetic activity due to leaf damage.
- Decrease in cane weight and plant vigor.
- Lower sugar content and poor juice quality.
- Yield losses of up to 30% in severe cases.

If not properly managed, the disease can spread throughout the entire field, causing extensive crop damage.

Economic Importance

Since sugarcane is a key contributor to the rural economy and sugar-based industries, outbreaks of Leaf Scald can lead to significant financial losses. The disease also affects ratoon crops (subsequent growing cycles), reducing long-term productivity and increasing management costs for farmers.

Detection Using Image Processing and Machine Learning

Traditional detection methods rely on visual observation of leaf streaks. However, early symptoms may resemble nutrient deficiencies, making accurate identification difficult.

Modern automated detection approaches utilize:

- Edge detection techniques (such as Canny Edge Detection) to identify linear streak patterns.
- Color analysis to detect abnormal white or yellow discoloration.
- Texture feature extraction to analyze vein pattern irregularities.
- Machine learning models to classify leaves as healthy or infected.

These advanced techniques enable early and accurate detection, supporting timely intervention and improved disease management.

Pokkah Boeng Disease of Sugarcane



Pokkah Boeng is an emerging fungal disease that primarily affects sugarcane during its early growth stages. The term “Pokkah Boeng” originates from a Javanese expression meaning “*distorted top*,” which reflects the characteristic deformation observed in the upper portion of the plant. In recent years, the disease has been increasingly reported in major sugarcane-growing regions, including India, making it an important concern for crop management.

Causal Organism

Pokkah Boeng disease is caused by fungal species belonging to the *Fusarium* genus, most commonly *Fusarium verticillioides* (previously known as *Fusarium moniliforme*). The pathogen mainly infects young and actively growing tissues, particularly the top portion of the plant.

Symptoms of Pokkah Boeng Disease

The symptoms of the disease progress through different stages depending on the severity of infection:

1. Chlorotic Phase (Initial Stage)

- Yellowing(chlorosis) of young leaves.
- Presence of light-colored streaks on leaf surfaces.
- Mild twisting and curling of leaves.

2. Twisting Phase

- Severe deformation and wrinkling of top leaves.
- Narrowing and shortening of leaf blades.
- Abnormal development of the spindle (central shoot).

3. Top Rot Phase (Severe Stage)

- Rotting of the upper portion of the plant.
- Emission of foul odor from infected tissues.
- Drying and death of the growing point.

The distortion and twisting of upper leaves remain the most distinctive indicators of Pokkah Boeng infection.

Mode of Infection and Spread

The disease spreads through multiple pathways, including:

- Airborne fungal spores.
- Infected crop residues present in the soil.
- Rain splash and irrigation water.
- Favorable environmental conditions such as high humidity and temperatures between 25°C and 35°C.

Young plants are particularly vulnerable, especially during the monsoon season when environmental conditions support rapid fungal growth.

Impact on Crop Growth and Yield

Pokkah Boeng disease affects sugarcane development in several ways:

- Disruption of normal leaf growth and structure.
- Reduction in photosynthetic efficiency.
- Weakening of plant architecture.
- Occurrence of top rot in severe cases.
- Decrease in cane weight and sugar content.

While mild infections may show partial recovery, severe infections can result in significant yield losses.

Economic Importance

Sugarcane is a key industrial crop used for sugar and ethanol production. Therefore, outbreaks of Pokkah Boeng disease can negatively impact both farm income and industrial supply chains. Additional costs for disease management and reduced crop quality further increase the economic burden on farmers.

Detection Using Image Processing and Machine Learning

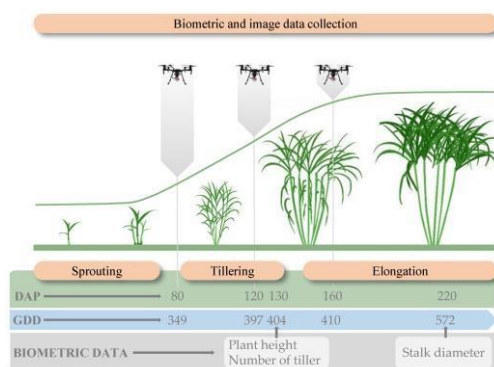
Traditional identification relies on visual observation of twisted and chlorotic leaves. However, early symptoms may resemble nutrient deficiencies, making accurate diagnosis challenging.

Modern detection systems employ advanced techniques such as:

- Canny Edge Detection to identify irregular leaf shapes and distortions.
- Color analysis to detect chlorotic (yellow) streaks.
- Texture feature extraction to analyze surface abnormalities.
- Machine learning algorithms to classify disease stages and severity.

These techniques enhance detection accuracy and enable early intervention, helping to prevent progression to severe stages such as top rot.

2. Literature Survey



The literature survey aims to analyze existing research work related to sugarcane disease detection using image processing and machine learning techniques. This section highlights previously developed methods, key findings, and the research gaps that motivate the proposed work.

2.1 Traditional Disease Detection Methods

Earlier approaches for detecting plant diseases were primarily based on manual field inspection carried out by agronomists and agricultural experts. These methods involved visual observation of changes in leaf color, shape, and texture to identify disease symptoms.

Kumar et al. (2017) reported that manual inspection methods are highly subjective and often fail to detect diseases at early stages due to subtle visual variations. In addition, such approaches are time-consuming, labor-intensive, and impractical for monitoring large

agricultural fields. These limitations highlight the need for automated and scalable solutions.

2.2 Image Processing Techniques for Disease Detection

With the advancement of digital imaging technologies, researchers have increasingly adopted image processing methods for plant disease diagnosis.

Singh and Misra (2018) utilized color segmentation techniques to detect infected regions on leaf surfaces. Their study emphasized the importance of converting RGB images into alternative color spaces such as HIS (Hue, Intensity, Saturation) for better separation of diseased areas.

Similarly, Gujjar et al. (2019) applied thresholding and region-based segmentation techniques to extract lesion areas from plant images. Their work demonstrated that image processing methods can effectively automate the detection of infected regions. However, these techniques alone are not sufficient for accurate disease classification, especially in complex scenarios.

2.3 Edge Detection and Feature Extraction

Edge detection plays a vital role in identifying boundaries of diseased regions in plant images. Among various techniques, the Canny Edge Detection algorithm is widely preferred due to its ability to detect fine edges while minimizing noise.

Patel et al. (2019) applied the Canny edge detection method to identify lesion boundaries in cotton leaf images and reported improved sensitivity in detecting infected areas. They concluded that combining edge detection with texture-based features enhances the accuracy of disease localization.

However, it has been observed that edge detection techniques alone cannot perform classification tasks and must be combined with feature extraction and classification methods.

2.4 Machine Learning-Based Approaches

To improve classification accuracy, researchers have integrated machine learning algorithms with image processing techniques.

- **Support Vector Machine (SVM):** Kumar and Singh (2020) utilized SVM classifiers trained on color and texture features for sugarcane disease detection. Their model achieved satisfactory accuracy but showed limitations when handling multiple disease categories.
- **K-Nearest Neighbors (KNN):** Singh et al. (2021) implemented the KNN algorithm using histogram-based features for leaf classification. While the method performed well for

simple binary classification tasks, it faced challenges with high- dimensional datasets.

- **Random Forest:** Gupta et al. (2021) explored the use of Random Forest classifiers with statistical features such as energy and entropy. Their results indicated improved stability and robustness compared to single classifiers, although larger datasets were required for optimal performance.

Overall, traditional machine learning techniques provide acceptable results for limited datasets but struggle with generalization across diverse environmental conditions and multiple disease types.

2.5 Deep Learning and Advanced Techniques

Recent advancements in deep learning have significantly improved the performance of plant disease detection systems. Deep learning models, particularly Convolutional Neural Networks (CNNs), can automatically learn complex features from images without manual feature extraction.

Sharma and Verma (2022) developed a CNN-based model for classifying sugarcane leaf diseases. Their approach achieved accuracy exceeding 90% for major disease categories, outperforming conventional machine learning techniques. The study demonstrated the effectiveness of CNNs in capturing complex patterns and variations in disease symptoms.

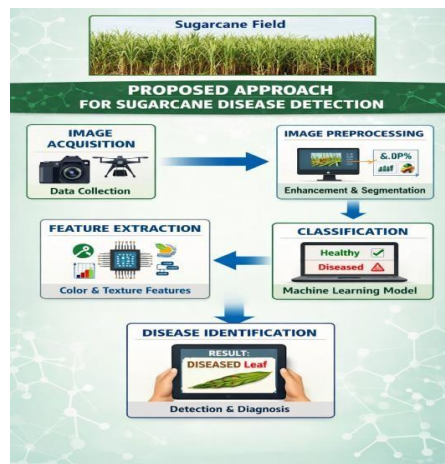
Research Gap Identified

Despite significant advancements, several challenges remain:

- Limited availability of large and diverse datasets.
- Difficulty in detecting diseases at early stages.
- High computational requirements of deep learning models.
- Need for cost-effective and real-time solutions for farmers.

These gaps highlight the necessity of developing an efficient and scalable system that combines image processing and machine learning for accurate and early disease detection.

3. Proposed Approach



The proposed system is designed to develop an automated and reliable solution for sugarcane disease detection using image processing and machine learning techniques. The primary objective is to identify diseases at an early stage from leaf images and assist farmers in taking timely preventive measures. The system integrates image acquisition, preprocessing, segmentation, feature extraction, and classification to achieve accurate disease identification. The overall methodology is divided into two main phases: the **training phase** and the **testing (detection) phase**.

3.1 Phase I – Training Phase

The training phase focuses on dataset preparation and model learning.

Step 1: Data Collection

- Collection of images of healthy and diseased sugarcane leaves.
- Images are captured using digital cameras, smartphones, or drone-based remote sensing systems.
- The dataset includes major diseases such as Red Rot, Smut, Rust, Mosaic, Leaf Scald, and Pokkah Boeng.

Step 2: Image Preprocessing

To enhance image quality and ensure uniformity, preprocessing techniques are applied:

- Resizing images to a standard dimension.
- Noise removal using filters (e.g., Gaussian filter).
- Conversion of RGB images to grayscale (if required).
- Normalization to improve contrast and brightness.

Preprocessing improves the consistency of the dataset and enhances detection performance.

Step 3: Image Segmentation

Segmentation is performed to isolate the leaf region and infected areas from the background:

- Thresholding techniques
- Color-based segmentation
- Region of Interest (ROI) extraction

This step ensures that only relevant portions of the image are analyzed.

3.2 Feature Extraction

Feature extraction plays a crucial role in identifying disease characteristics. The following techniques are used:

1. Canny Edge Detection

- Detects boundaries of lesions and infected regions.
- Identifies irregular leaf edges and disease spots.
- Reduces noise while preserving important structural details.

2. Color Histogram Analysis

- Analyzes color distribution within the leaf image.
- Detects abnormal variations such as yellowing, browning, and discoloration.

3. Texture Feature Extraction

- Captures surface patterns and irregularities.
- Extracts statistical features such as contrast, entropy, and homogeneity.

All extracted features are combined into a feature vector for classification.

3.3 Algorithm for Disease Detection

The proposed algorithm performs automatic classification of sugarcane leaf diseases using sequential steps:

Input

- Sugarcane leaf image (captured via camera or drone)

Output

- Disease classification (Healthy or specific disease type)

- Suggested treatment and confidence score

Step 1: Image Acquisition

1. Capture leaf images using:
 - a. Digital camera
 - b. Smartphone
 - c. UAV/Drone
2. Store images in the dataset.

Step 2: Image Preprocessing

3. Resize image to a standard size (e.g., 256×256 pixels).
4. Apply noise removal filter (e.g., Gaussian filter).
5. Convert image to grayscale if required.
6. Normalize image intensity.

Step 3: Image Segmentation

7. Apply thresholding or color-based segmentation.
8. Extract Region of Interest (ROI) containing infected areas.

Step 4: Feature Extraction

9. Apply Canny Edge Detection to identify lesion boundaries.
10. Perform color histogram analysis.
11. Extract texture features such as:
 - Contrast
 - Energy
 - Homogeneity
12. Store features in vector form.

Step 5: Model Training (Training Phase)

13. Split dataset into training and testing sets.
14. Train machine learning models such as:
 - Support Vector Machine (SVM)
 - K-Nearest Neighbors (KNN)
 - Random Forest
15. Save the trained model.

Step 6: Disease Classification (Testing Phase)

16. Input a new leaf image.
17. Apply preprocessing and feature extraction steps.
18. Feed extracted features into the trained model.
19. Predict disease class:
 - Healthy
 - Red Rot
 - Smut
 - Brown Rust
 - Mosaic
 - Leaf Scald
 - Pokkah Boeng

Step 7: Output Result

20. Display predicted disease name.
21. Provide confidence score.
22. Suggest suitable treatment or pesticide.

CONCLUSION

Sugarcane is a vital commercial crop cultivated in countries such as India, Brazil, and Thailand, contributing significantly to the agricultural economy and sugar-based industries. However, its productivity is adversely affected by a wide range of diseases caused by fungi, bacteria, and viruses, including Red Rot, Brown Rust, Smut, Wilt, Pokkah Boeng, Mosaic, and Grassy Shoot disease. These diseases lead to reduced cane yield, lower sugar recovery, and deterioration in overall crop quality, ultimately resulting in substantial economic losses.

The comprehensive study of these diseases highlights several important observations. Fungal diseases such as Red Rot, Rust, Smut, and Wilt are highly aggressive and tend to spread rapidly under favorable environmental conditions. Viral diseases like Mosaic and Grassy Shoot are primarily transmitted through infected planting materials and insect vectors, making their control more challenging. Additionally, bacterial infections further weaken plant health and contribute to increased damage. In most cases, early symptoms appear on leaves, stems, or internal tissues; however, timely detection remains a challenge for many farmers.

Conventional disease detection methods, which rely on manual inspection and expert knowledge, are often time-consuming, labor-intensive, and prone to inaccuracies, especially

in large-scale farming environments. These limitations emphasize the need for modern, technology-driven solutions.

The integration of image processing and machine learning techniques provides an effective approach for automated disease detection. By analyzing leaf images, such systems enable early and accurate identification of disease symptoms. This approach offers several advantages, including reduced dependency on expert supervision, faster decision-making, cost-effective monitoring, and improved crop productivity.

In addition to technological solutions, effective disease management requires the adoption of good agricultural practices such as the use of disease-resistant varieties, certified healthy planting material, proper crop rotation, field sanitation, and timely application of chemical or biological treatments.

In conclusion, the combination of traditional agricultural practices with advanced technologies such as Artificial Intelligence and Deep Learning has the potential to transform disease diagnosis in sugarcane cultivation. This integrated approach can enhance sustainability, improve yield quality, and support farmers in achieving more profitable and efficient agricultural production.

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