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Advancements in Crop Disease Detection: Analytical Methods for Recognizing Disease Stages through Leaf Analysis

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Abstract: - Plant diseases have the potential to damage the livelihoods of farmers and impede their capacity to generate an adequate quantity of food. Diagnosis and early detection of plant diseases are critical for their effective management and control. Leaf analysis shows great potential as a method for forecasting disease stages due to its ability to detect subtle alterations in leaf physiology and appearance that may occur prior to the onset of conspicuous symptoms. By utilizing the algorithms of machine learning and deep learning, it is possible to classify characteristics extracted from photographs of leaves into distinct disease stages. Recent studies have demonstrated the potential of these algorithms, as they have achieved remarkable accuracy in disease stage prediction despite having limited training data. The integration of machine learning and deep learning techniques with foliage analysis holds promise for revolutionizing plant disease management through the provision of timely identification, accurate diagnosis, and customized treatment. In order to formulate efficacious disease management strategies, precise determination of the developmental stage of plant diseases is imperative. Scholars are presently devising novel approaches to identify the stages of plant diseases by employing diverse methodologies, including spectroscopy, machine learning, and image processing. This can benefit producers in substantial economic and environmental ways, as well as contribute to the improvement of food security. The primary investigation comprises an assortment of articles spanning the years 2014 to 2023. After evaluating various search strategies, a total of 117 research publications were identified, of which 43 were pertinent. The article examines numerous developments in deep learning research. In addition, it will facilitate the assessment of the present and prospective state of plant disease research by employing deep learning methodologies.

Keywords: Chlorophyll Pigmentation, Deep Learning, Disease Stage Classification, Early Detection, Feature Extraction, Leaf Analysis.

I. Introduction

Plant diseases can result in crop losses leading to decreased food production and financial challenges for farmers. It is crucial to detect and diagnose plant diseases for management. However traditional methods like inspection by trained experts can be time consuming. Require significant labour. Growing interest has been seen in creating automated systems that use machine learning and image processing to identify plant diseases over time. These advanced systems have the potential to revolutionize disease management by providing farmers with an accurate means of detection and diagnosis. One of the challenges in automated plant disease detection is accurately determining the stage of disease development as it greatly influences symptom severity and treatment effectiveness. Detecting diseases at a stage allows for treatment with minimal crop losses. This review paper's objective is to

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present the state of-the-art techniques for identifying the stage of plant diseases using leaf photographs. This area of research is vital as timely disease detection at a stage is essential for effective management.

Reliable and precise detection systems for plant disease stages have the potential to bring about a revolution in plant disease management. These systems can assist farmers in identifying diseases at a stage when they are easier to treat and less likely to result in crop damage. This could potentially result in a decrease in the reliance on pesticides and other chemicals ultimately mitigating their effects on the environment and economy. Moreover, the implementation of plant disease stage detection systems can greatly enhance crop quality and yield. By offering farmers a precise means of identifying and diagnosing plant diseases such systems play a role in enhancing food security and minimizing economic losses within the agricultural industry [32].

The aim is to examine the body of literature and identify the obstacles and possibilities to stimulate fresh research in this field and expedite the advancement of more efficient systems for detecting plant disease stages. This review paper's goal is to provide an examination of innovative techniques used to identify early stages of plant disease using leaf photos. We delve into techniques involving image processing and machine learning that have been utilized for this purpose while also assessing their performance, across datasets.

II. Review Methodology

A plant's leaves are one of its three organs. A leaf's main job is to provide nutrition for the plant. The leaf is the main organ, though not the only one, that uses sunlight to produce nourishment. Leaves differ in size, shape, and texture according to what works best for them in their natural habitat. Sunlight, which is absorbed by the green pigment found in most leaves, is one of the essential elements in the food production process. Leaf markings are among the most common indicators of any disease, whether caused by bacteria, viruses, or fungi. These diseases can also be identified by sudden wilting, ragged or curling leaves, deformed fruit, or flowers, typically discolored or mottled foliage, and poor growth. Fig.1 and 2 basically show the reviewed research paper and progress of research respectively.

Among the common plant diseases are those caused by fungi, bacteria, and viruses. Powdery mildew, rust, black spot, and botrytis blight are examples of fungal infections. Blight, Leaf Spot Wilt, Soft Rot, Bacterial Canker, and Black Rot are examples of bacterial infections. Leaves are the primary entry point for most plant diseases. The leaves are the most important element of a plant since they are responsible for the process of photosynthesis, the process by which the plant gets energy from the sun. We can tell if the plant is infected by looking at its leaves. There are different types of leaf diseases that is described as:

BIOTIC	**ABIOTIC**
Living organisms	Non-living organisms
Fungi, bacteria, viruses, nematodes, and parasites are among the living things that can cause biotic leaf diseases.	Non-living elements such environmental stresses, dietary excesses or deficiencies, physical harm, and chemical injuries are the root cause of abiotic leaf diseases.
Several media, such as water, air, soil, plant waste, insects, and other vectors, can facilitate the spread of these diseases.	Rather than being produced by pathogenic organisms, the symptoms of abiotic leaf diseases frequently present as physiological problems or damage from environmental factors.
Biological control, which uses beneficial organisms to suppress disease-causing organisms, chemical control, which uses fungicides, bactericides, or pesticides, and cultural practices.	Abiotic leaf diseases do not transfer from one plant to another and are not communicable. Usually, they are restricted to plants or parts of a plant.
Examples: powdery mildew, Spot infections on rust leaves, Leaf blight caused by bacteria Viral infections.	Examples: Heat exhaustion or sunburn, Damage from frost or freezing, Deficits or toxicities in some nutrients.

The research approach that is being described is based on a review of the literature that is specific to diverse studies. The main objective of the paper's writing is to give a fair approach to a research-based problem using exact, astute, and tried-and true methodology. Considered the journals and research papers that help to achieve the goal among the available approaches in the numerous papers reviewed. Numerous prior studies that are relevant to the research issue are located at various levels. The research questions are described, the review standard is specified, and the requirement for writing the review is determined during the review process. The preliminary studies are now chosen, the studies needed to evaluate the features are identified, the data abstraction and assessment are carried out, after which the data is analysed. Before the review step is discussed, the publication channels are described, and the review report is given.

A. Inclusion-Exclusion Criteria

We gather research papers from libraries using different keywords associated with image processing, machine learning and identifying stages of plant diseases. During the review process we consider research papers and articles that explain techniques, employing techniques like image processing, machine learning algorithms, and deep learning models to find disease stages in leaves. However, we exclude research papers that primarily focus on evaluating predetermined software metrics from our review. We prioritized papers with accessible datasets and clear presentation. We investigated picture preprocessing approaches, feature extraction techniques, machine learning algorithms for classification, and performance evaluation measures while conducting a thorough examination of a few chosen studies.

several terms related to deep learning, soft computing, texture analysis, and leaf analysis. Pigmentation was utilised to look for pertinent articles from several online resource centres. Research papers and articles that detail the examination of leaf texture, shape, colour, and pigmentation are part of the analysis process. The evaluation of algorithms and approaches was the main emphasis of research publications that were not written in English. 42 of the over 117 research publications and articles that were gathered are used in the current paper. The classification of the included research publications is shown in Table 1.

Table 1. Research Progress in Years

Year	Total Number of Papers	% Proprtion
2015	1	2.38
2016	1	2.38
2017	3	7.14
2018	2	4.76
2019	5	11.9
2020	5	11.9
2021	8	19.05
2022	7	16.67
2023	10	23.81

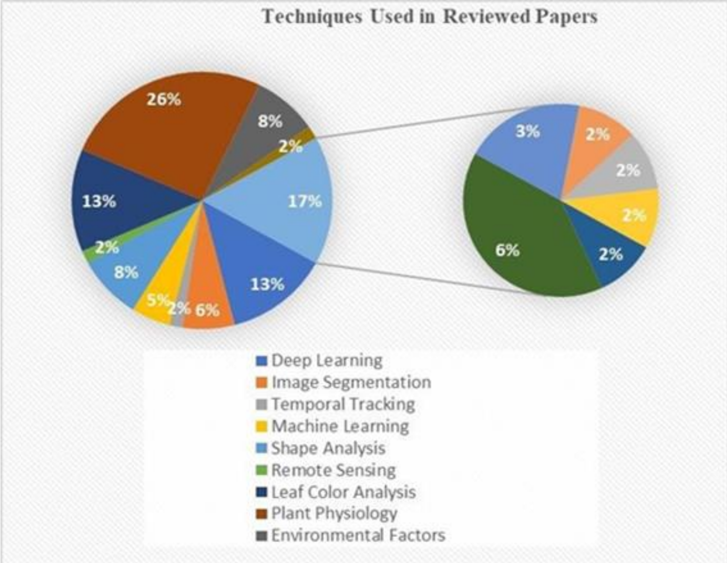

Figure 1. Techniques Used in Reviewed Research Papers

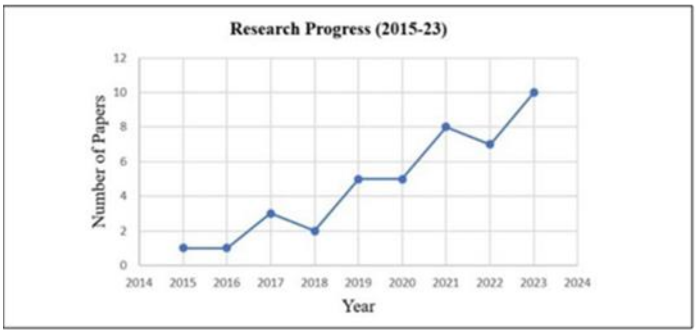

Figure 2. Research Progress in Years

B. CNN Selection and Model Optimization

The choice of a Convolutional Neural Network (CNN) for plant disease image classification is apt due to its inherent ability to recognize complex spatial patterns [33]. The dataset, containing plant disease images, aligns well with CNN's proficiency in systematically learning and generalizing intricate features associated with diverse diseases. Through careful dataset splitting, preprocessing, and model training, the CNN efficiently captures and classifies plant diseases. Fig. 3 shows the leaf image and disease percentage by using the trained model. The model's architecture, consisting of convolutional and dense layers, is tailored for optimal performance. Training history visualization and predictions on test images succinctly demonstrate the model's efficacy in accurately identifying plant diseases. This streamlined approach ensures the CNN's effectiveness in addressing the dataset's challenges, providing a robust solution for plant disease classification.

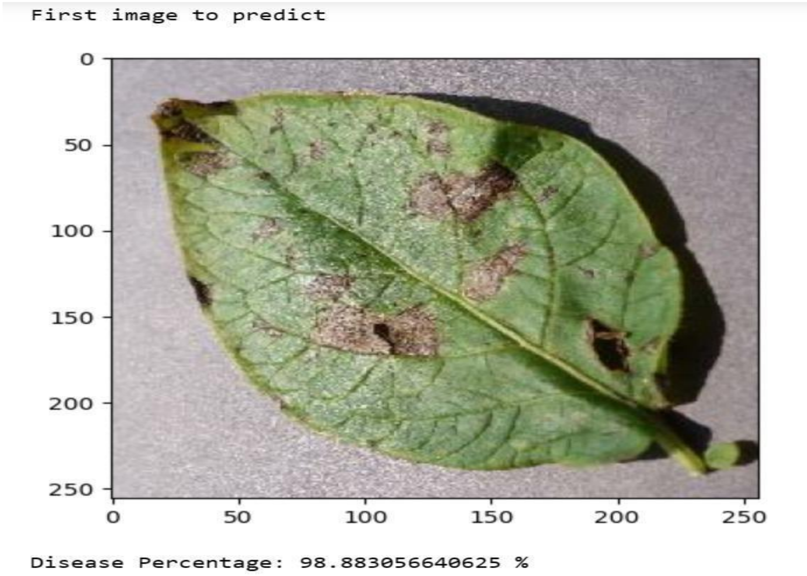

Figure 3. Trained model using area and shape of the leaf.

C. Freshness Factor Computation through Color Analysis

The freshness factor determination involves converting the image to RGB to extract pixel-wise RGB values, offering a comprehensive color representation. Subsequent transformation to the HSV color space isolates the Hue values, representing the specific shade of green. Average RGB values contribute to assessing overall greenness and darkness, while the average hue captures nuanced green shades shown in fig.4. The fusion of these RGB and Hue factors results in the freshness factor, offering a nuanced measure of leaf freshness based on its color characteristics.

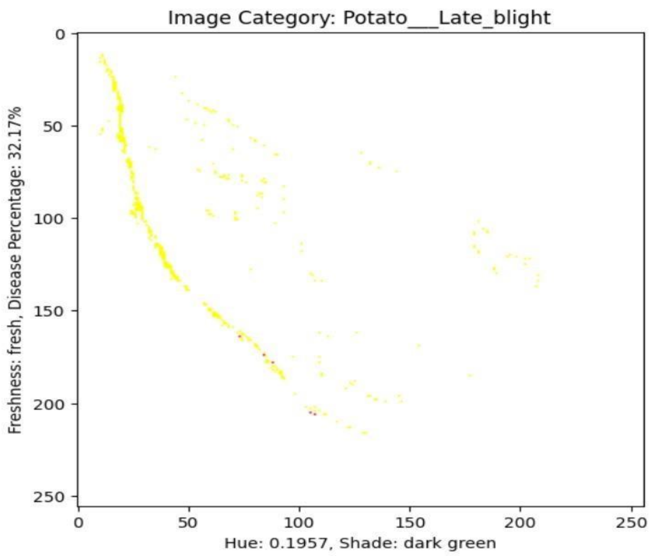

Figure 4. Trained model using hue average of the leaf.

D. Research Questions

Based on the results of the literature analysis, two research related questions were developed.

RQ1.Can we do the disease stage using a certain part of plant.

RQ2.What are the possible factors for predicting the disease.

III. Dataset Analysis

There are 3 types of datasets used to study the relationship between leaf color change and severity of plant diseases – Correlational dataset, Casual dataset, Image Dataset

Co-relational Dataset - contains data on two variables for a variety of plant species and diseases which is then used to investigate the relationship between those 2 variables (E.g., leaf color changes and disease severity). Negative: Lighter colored leaves have more severe disease. Positive: Darker colored leaves have more severe disease.

Casual Dataset - contain data on leaf color, disease severity, and other variables that could influence leaf color change, such as nutrient levels, environmental conditions, and the presence of other diseases which is then used to investigate the causal mechanisms underlying the relationship between leaf color change and plant diseases.

Image Dataset - contain images of leaves with different degrees of leaf color change and different types of diseases which could then be used in image analysis software to extract features from the images, such as leaf color and leaf texture and then we can use these features to develop machine learning models that can classify leaves as healthy or diseased based on their leaf color change. Fig. 5 indicates that Image datasets are the most widely used datasets.

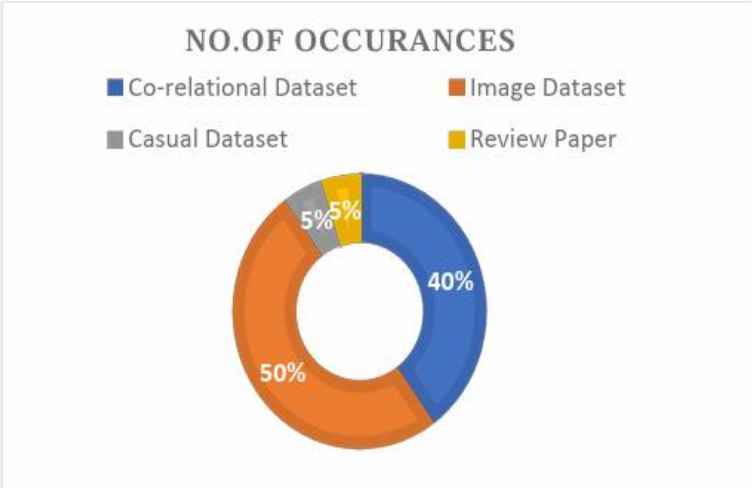

Figure 5. Types of Datasets

IV. Literature Review

Deep learning and machine learning are transforming the diagnosis and treatment of plant diseases [34]. By extracting features from leaf images and other data, these machine learning models can be trained to predict disease stage and provide tools to help farmers and producers. Although there are difficulties with plant form analysis, diagnostic methods such as leaf colour change, and leaf wetness duration can be helpful. The severity of the disease is also influenced by temperature, humidity, drought stress, and nitrogen fertilisation. Researchers are developing novel methods for classifying, managing, and diagnosing plant diseases using machine learning, deep learning, and integrated pest management. Different classification techniques are shown in fig.6 that have used by the different authors. Two crucial markers of plant health and stress are the amount of chlorophyll and the fragility of the leaves [35]. Table 2 represents the different proposed methodologies.

Table 2. Represents Purposes with their Methodologies.

Methodology	**Purposes**	**Paper Reference**
Deep Learning	Plant disease classification	[1]
	Plant disease segmentation subtype identification, and survival probability estimation	[2]
	Plant disease detection and classification	[3]
	Crop disease and nutrient deficiency detection	[4]

	Potato late blight disease detection	[5]
	Plant disease temporal tracking	[6]
Machine Learning	Plant disease detection	[7]
Shape Analysis	Plant fungal disease detection	[8]
	Plant viral disease detection	[9]
	Plant insect damage assessment	[10]
	Plant disease detection and classification	[11]
	Plant disease progression monitoring	[12]
Leaf color Analysis	Relationship between leaf color and disease severity in wheat	[13]
	Leaf color change as a diagnosis tool for plant diseases	[14]
	Relationship between leaf color and disease severity in maize	[15]
	Effect of leaf color on disease severity and yield of rice	[16]
	Impact of leaf spot disease on the fruit quality of apple trees	[17]
	Direct quantitative evaluation of disease symptoms on living leaves	[18]
Leaf wetness Analysis	Relationship between leaf wetness duration and severity of early blight disease	[19]
Environmental Analysis	Effect of temperature and humidity on the development of powdery mildew	[20]
	Influence of environmental factors on severity of rust disease	[21]
Field experiment and laboratory Analysis	Effect of environmental factors on plant diseases	[22]
Computer vison and Machine learning	Plant leaf disease detection and classification	[23]
Leaf frailty Analysis	Chlorophyll pigment content and leaf frailty as indicators of salt stress	[24]
	Effect of chlorophyll pigment on leaf frailty in soyabean	[25]
	Chlorophyll fluorescence content and leaf frailty measurements as indicators of drought stress	[26]
Review	Machine learning and deep learning for disease detection in plant leaves	[27]
Soft computing	Image segmentation and soft computing approaches for plant leaf disease detection	[28]
Chlorophyll pigment	Chlorophyll pigment and leaf macronutrients and variation of four willow species in elevated CO2, under soil moisture stress and fertilization treatments	[29]
Texture feature analysis	Hybrid system for detection and classification of plant disease using qualitative texture features analysis	[30]
	An overview of the research on texture-based plant leaf classification	[31]

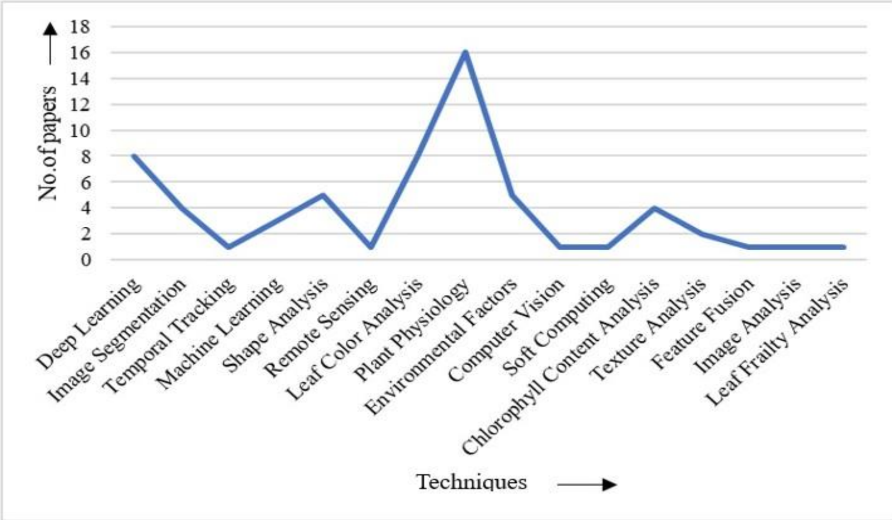

Figure 6. Classification of Techniques

V. Result And Analysis

This paper's major goal is to examine the difficulties associated with predicting disease stages through leaf analysis and how these difficulties might be overcome using soft computing techniques. This section offers the research question's overall evaluated solution.

RQ1. Can we do the disease stage using a certain part of plant.

Yes, it is feasible to determine the disease stage by focusing on a specific section of the plant. This method is rather prevalent in the field of plant pathology. The disease type and stage would determine which plant section to check. For example, while examining leaf rust disease in wheat, pathologists generally examine the leaves for rust pustules. These pustules are elevated formations that carry disease-causing spores. By evaluating the size, number, and distribution of these pustules, one can accurately estimate the stage of the disease in question. This technique contributes to the development of plant disease management strategies.

RQ2.What are the possible factors for predicting the disease

Leaf analysis helps growers and farmers take precautions to protect their crops by forecasting the stage of illnesses. For example, producers can protect a plant against infection by applying fungicide if a model suggests that the plant is prone to infection. In a similar vein, eliminating a plant that the model indicates is susceptible to illness can stop it from spreading to other plants. Additionally, leaf analysis aids in the identification of weak plants, which improves crop production. Growers can promote plant growth and boost fruit and vegetable production by taking care of these problems. In conclusion, leaf analysis becomes useful for predicting disease stages, identifying plants, and formulating early intervention plans to support plant health and maximising agricultural yield.

VI. Conclusion

Plant diseases can be detected, segmented, classified, tracked over time, and their extent assessed with the help of machine learning and deep learning. Plant diseases may be accurately identified and categorised by training learning algorithms based on features such as leaf shape, colour, and texture. The fact that these models can get accuracy with a small amount of training data is impressive. Furthermore, we can estimate the severity and stage of plant diseases using plant form analysis and leaf colour analysis. The study of machine learning and deep learning has the potential to completely change how we detect and manage plant diseases. It may make identification, accurate classification, and efficient therapy easier. There are still obstacles to be addressed, though. These include gathering a variety of datasets, building effective models, and fusing deep learning and machine learning with other technologies, such as precision agriculture and remote sensing, in a seamless manner.

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