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Artificial intelligence approaches for cotton diseases identification: a systematic literature review using biotechnology

Manish Nandy

*Corresponding Author. Assistant Professor, Department of CS & IT, Kalinga University, Raipur, India. E-mail address: ku.manishnandy@kalingauniversity.ac.in

Ahilya Dubey

Research Scholar, Department of CS & IT, Kalinga University, Raipur, India. E-mail address: ahilya.dubey@kalingauniversity.ac.in

Abstract

Objective

Cotton is a prominent fiber that commands the worldwide industrial and agricultural sectors. Cotton is a fundamental material used in the creation of textiles. Diagnosing the diseases on cotton plants' leaves soon is essential to prevent them and enhance productivity. Tracking cotton leaf illnesses and assessing plant health is challenging for farmers who rely solely on their subjective expertise and knowledge. Moreover, Artificial neural networks have been proposed to alleviate limitation of traditional methods and can be used to handle nonlinear and complex data, even when the data is imprecise and noisy. Agricultural data can be too large and complex to handle through visual analysis or statistical correlations. This has encouraged the use of machine intelligence or artificial intelligence The objective of this study was to diagnose diseases and improve the cultivation of cotton using Artificial Intelligence (AI) methods.

Results

The study findings indicate that the current automated detection approaches for cotton crop illnesses are still in their early stages of development with biotechnology and Artificial Intelligence (AI). This review acknowledges the need to develop automated, cost-effective, dependable, precise, and swift diagnostic tools for detecting cotton leaf diseases to enhance output and quality.

Conclusions

This paper analyzes the several computational techniques used at different phases of plant-pathogen structures, including image preparation, segmentation, extracting features and selecting, and categorization. The study identified valid future paths and areas for additional exploration. There is a need for innovative, fully automated computer-assisted methods to identify and categorize various illnesses in cotton crops.

Keywords: Artificial intelligence, biotechnology, cotton crop, cotton diseases

Paper Type: Review Paper.

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Introduction

Cotton, scientifically known as Gossypium hirsutum L., is a crop of significant commercial value (Huang et al. 2021). Cotton is the primary provider of natural textile fiber and an essential oil crop. Cotton is comprised of 49 species that are found in various tropical and subtropical climates across the globe. The global cotton industry is a lucrative business, including the entire process from cultivating raw fiber to manufacturing completed textile goods. Cotton crops suffer substantial financial losses due to illnesses and insect infestations (Karthika et al. 2021). If left unmanaged promptly during the first stages, these pests can lead to an infestation, resulting in a decreased yield and compromised product quality. Entomological and pathogenic issues contribute to reduced cotton yields and revenue losses. Agrochemicals are employed to manage illnesses and insect pests; however, their use leads to an escalation in production expenses and has detrimental effects on the surroundings (Karthika et al. 2021). Integrated Pest Management (IPM) aims to reduce the ecological consequences of pesticide use and mitigate any threats to human and animal well-being (Deguine et al. 2021). IPM is founded on two crucial elements - avoiding and tracking illnesses and insect pests - currently supported by sensing and Artificial Intelligence (AI) methodologies (Orchi et al. 2021). Advancements in manufacturing automation, assembly-line industrial inspection structures, and healthcare imaging have been achieved through object recognition and AI research with biotechnology (Mumtaj Begum, 2022). Computer vision has significantly contributed to the progress of precision agriculture by enhancing the identification of illnesses and insect pests (Angin et al. 2020). Aside from computer vision, using temperature, soil, and moisture detectors enables data collection to be analyzed and forecasted using biotechnology (Steinwand & Ronald 2020; Yağız et al. 2022). Moreover, data generation in agriculture and biotechnology has greatly increased in recent years due to the very rapid development of high-performance technologies (Mohammadabadi et al. 2024). These data are obtained from studying products, foods, and biological molecules to understand the role of different aspects of agriculture in determining the structure, function, and dynamics of living systems (Pour Hamidi et al. 2017). Artificial neural networks have been proposed to alleviate limitation of traditional methods and can be used to handle nonlinear and complex data, even when the data is imprecise and noisy (Pour Hamidi et al. 2017). Agricultural data can be too large and complex to handle through visual analysis or statistical correlations. This has encouraged the use of machine intelligence or artificial intelligence (Ghotbaldini et al. 2019). Thus, this study aimed to determine the most advanced research on the control (identification, forecasting, diagnosis, and treatment) of illnesses and infestations of insects in cotton. The primary contributions of this article are as follows: The cotton illnesses and insect pests were studied using AI and sensing approaches between 2000 and 2023. A thorough examination of the chosen articles. This research defines and analyzes the difficulties faced in utilizing AI methods to manage pests and diseases in the cotton industry.

Workflow of the disease detection

The utilization of computational approaches is crucial in the automated detection and avoidance of plant diseases to optimize the productivity and accessibility of cotton with biotechnology. Figure 1 provides an overview of the AI-based pathogen apparatus for cotton crops, including the framework and methodologies scientists use at each network level (Radhika & Masood 2022).

Preprocessing: Preprocessing approaches aim to minimize undesirable distortion and enhance distinctive image elements as an essential component of the biotechnology plant disease diagnostics system (Dhiman et al. 2023). The farmer utilizes a camera or smartphone to record photographs of the cotton area, which generally contain noisy and low-quality data using biotechnology. Various preprocessing approaches have been developed to eliminate noise and extraneous objects from pictures (Surendar et al. 2024). A study has been conducted on the preprocessing techniques to create a high-quality image to detect diseases in cotton plants (Sharma et al. 2020).

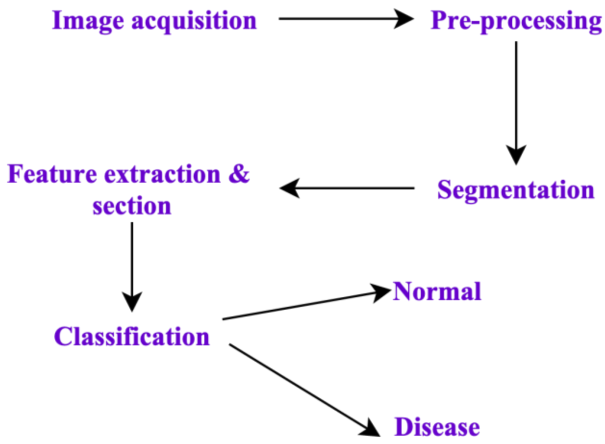

Figure 1. Workflow of the disease detection model

The median filter is a quantitative filter of higher order (Sharma et al. 2020). The process is intrinsically nonlinear as it involves replacing the central pixel's value with the mean of the grayscale in the picture area encompassed by the filter. The mean of a specimen is a number that separates the sample into two halves, with half of the values being below or comparable to the median and the other half being higher or closer to the median (Gladkov & Gladkova 2021). Applying a Median Filter improves the quality of the cotton leaf photos. The K-Means method is used to identify diseased spots on cotton leaves (Yu et al. 2021). These spots' color and textural features are analyzed to diagnose illnesses using biotechnology. The findings indicated that the Multi-stage Support Vector Machine (SVM) achieved an accuracy of 81.6%, surpassing the Convolutional Neural Network (CNN) by 6%. The research exhibits a lower susceptibility to excessive fitting (Camgözlü & Kutlu 2023). Kumar et al. developed a system that utilized image-processing techniques to eliminate picture noise (Dhiman et al. 2023). They used a Regions of Interest (RoI) method to extract the diseased areas in cotton leaves. They employed the Gray Level Co-occurrence Matrix (GLCM) approach to obtain the necessary features from the cotton leaves.

Segmentation: Extracting the infected area in plant images is crucial for identifying the specific type of disease affecting the leaves of cotton crops (Divyanth et al. 2023). The image segmentation technique divides the image into many parts. Methods for segmentation such as thresholding, K-Means clustering, Fuzzy C-Means approaches, histogram, and graphs cut

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approaches are commonly used to identify the impacted area in plant leaf photos using biotechnology. This section presents segmented techniques for determining a damaged area in photos of cotton plants (Karthika et al. 2021). The graphical representation of these algorithms can be shown in Figure 2.

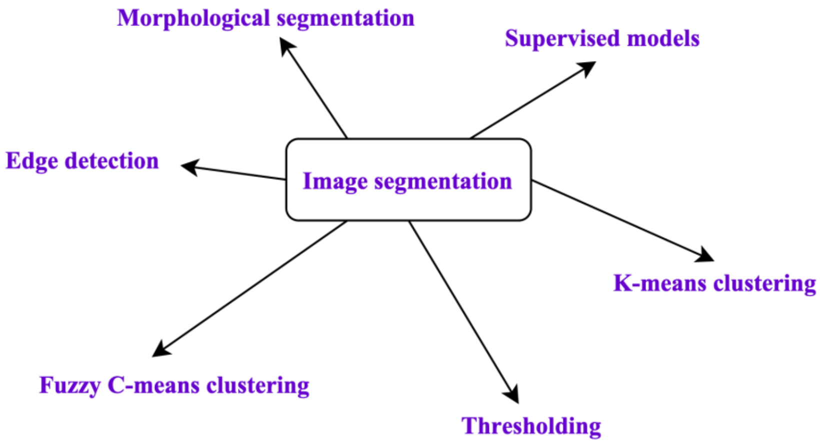

Figure 2. Segmentation process

Camgözlü & Kutlu (2023) devised an image-processing method to detect visual indicators of plant diseases by analyzing color photographs (Mao et al. 2020). The histogram approach is employed to partition the converted image into multiple regions by examining the distribution of intensities. Area thresholding methods are used to identify the presence of mite infections in photographs of cotton leaves. The technique successfully identified the affected area, achieving an average accuracy rate of 82.1% in extracting it. The highest magnitude of the deprived leaf was less than that of the regular leaf using biotechnology (Sharma et al. 2020). An RGB spectrum captures a picture of the cotton leaf using a high-resolution sensor with 16 megapixels. The LAB color separation is again used for defective leaves, measuring the Luminance at various points and the illumination of other places on the affected leaf. The K-means technique employs an Euclidean distance metric to measure the separation between multiple groups to locate spots. This is done by computing GLCM features to identify diseases based on leaf characteristics. The Otsu thresholding method is suggested for determining the affected region in the photos of cotton plants. The findings indicated that Otsu outperformed global thresholds in segmenting the sick region (Vasconcelos et al. 2023).

Feature extraction and selection

Feature extraction is crucial in developing the image categorization algorithm for gathering vital information to define each class (Vishnoi et al. 2022). Features associated with objects are

calculated and combined into a feature vector. Classifications utilize this vector to identify the data to be classified. Feature extraction is to identify and select a specific collection of attributes that accurately and distinctly define the photos. The feature selection and optimization methods aim to identify a subset of features that contains the most critical and relevant characteristics from a more extensive set of characteristics. K-Means clustering was utilized to identify the affected regions in images of tomato plants (Basavaiah & Arlene Anthony 2020). GLCM feature sets were computed and then passed to a neural network (NN) to categorize illnesses in the leaves of plants. Xiong et al. devised a framework consisting of three sequential processes for image segmentation (Xiong et al. 2020). The first step involved utilizing K means clustering to determine the affected region. The second step involved feature extraction utilizing the GLCM method. The third step involved classifying cotton diseases into infected or non-infected plant varieties using an SVM.
Verma & Meesala (2022) utilized the Fuzzy Curves and Surfaces (FCS) method to calculate the statistical parameters of cotton leaf images (Verma & Meesala 2022). They selected the most optimal collection of features based on a Mean Squared Error (MSE) value of 0.27. The minimum MSE implies that the N-dimensional fuzzy surface provides the most accurate framework for matching the input to output information using biotechnology. Dong et al. developed a methodology combining Case-Based Reasoning (CBR) with fuzzy logic techniques to accurately diagnose illnesses affecting cotton leaves (Dong et al. 2021). The dataset contains cotton leaves exhibiting various diseases. The suggested method achieved a diagnostic accuracy rate of 87.5%.

Classification: Plant diseases can cause significant damage to natural ecosystems and exacerbate environmental issues (Sakkarvarthi et al. 2022). Farmers employ visual inspection to observe and comprehend the state of cotton plants. The farmer is exhausted from the repetitive and ongoing monitoring of cotton leaves on expansive farms using biotechnology. Farmers can incorrectly identify cotton illnesses by manually observing symptoms and indications or relying on their expertise. Automatic categorization allows farmers to identify diseases in cotton plants, enabling them to implement preventive actions to enhance the yield and accessibility of cotton (Dong et al. 2021). Various models for classification, including Principal Component Analysis (PCA), Random Forests, SVM, K-Nearest Neighbout (K-NN), Multilayer Perceptron (MLP), Artificial Neural Network (ANN), Probabilistic Neural Network (PNN), Back Propagation Neural Networks (BPNN), and Convolution Neural Networks (CNN), have been investigated in research on agriculture to identify cotton plant illnesses (Kumar & Sathish Kumar 2022). Various studies have utilized multiple categorization systems to diagnose diseases in cotton plants, as shown in Figure 3.

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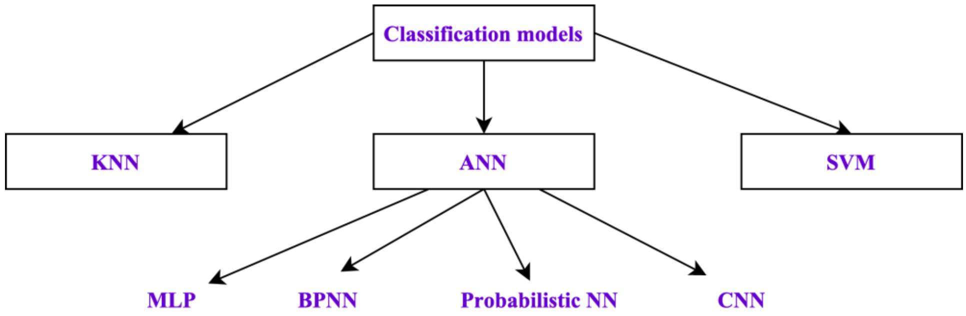

Figure 3. Classification models

K-NN is a supervised learning technique widely used in the recognition of patterns, detection of intrusions, and data extraction. K-NN utilizes a similarity function to make predictions for a new instance. The K-NN algorithm assumes the similarity of the latest example with the previous case and classifies the new object into the most similar group. The classification method utilized PCA and K-NN to detect various illnesses affecting cotton leaves accurately (Dhiman et al. 2023). An SVM is a supervised categorization technique specifically designed to determine the ideal decision limit, known as a hyperplane, for dividing n-dimensional characteristics into various categories. It is used to forecast the group to which newly arrived data points belong. The SVM technique uses biotechnology to construct hyperplanes by selecting extreme locations or vectors called support vectors (Steinwand & Ronald 2020). Thaiyalnayaki & Joseph (2021). employed SVM to detect cotton leaf illnesses (Thaiyalnayaki & Joseph 2021). K-means clustering identifies the sick area by constructing a Gray-Level Co-Occurrence Matrix (GLCM) to calculate the textural characteristics. The SVM classifier detected illnesses in cotton leaves, including bacterial attacks, magnesium deficiencies, and poor health, with a precision rate of 81.5%. ANNs are mathematical representations directly inspired by biological NN and partially built upon them. They can simulate and handle nonlinear interactions simultaneously between inputs and outcomes. The K-means clustering method was used to divide the affected region in the leaf images into segments, and the Color Co-occurrence Method (CCM) was developed to calculate ten texture features. NNs detect leaf infections by analyzing extracted attributes (Sharma et al. 2020). The system comprises three tiers: data, application, and interaction.

Mobile applications: Many sophisticated intelligence systems have been created to detect and identify plant illnesses (Divyanth et al. 2023). By utilizing satellite and Smartphone programs, monitoring and tracing crops and vegetation is feasible, thereby mitigating the spread of epidemics and enhancing productivity. Here is the smartphone application designed to discover diseases on plant leaves. Mohiddin et al. developed a mobile terminal-based system called the cotton pest illness collection method (Mohiddin et al. 2024). The system is composed of four levels: the user layer, which is in charge of collecting and updating information on illnesses and pests; the network tier, which connects the application tier and the data tier; the application tier, which handles the functioning of the platform; and the data tier, which keeps all forms of data connected to illnesses and pests using biotechnology. Vasconcelos et al. created a terrestrial agricultural robot (Vasconcelos et al. 2023). This technology addresses the challenges encountered in implementing extensive and intricate satellite-based systems. It offers compact, portable, and dependable platforms for automated agriculture surveys, disease detection, and spraying of pesticides. The classification of cotton crops takes into account magnesium shortage and bacterial blight. An Android application utilizing Raspberry Pi has been created to detect cotton leaf pathogens and monitor the state of the soil. The afflicted section is obtained using thresholding methods, where textural parameters are calculated utilizing the Partial Least Square Regression (PLSR) methodology (Mohiddin et al. 2024). The SVM algorithm is used to identify illnesses in cotton leaves by examining the collected features. The SVM achieved a total precision of 79.23% in classifying the pathogens in cotton leaves.

Results and Discussions

Plants have a crucial role as a substantial energy source and a fundamental component in addressing the issue of global warming (Deguine et al. 2021). Multiple illnesses harm plants, leading to significant economic, social, and environmental damage. Agricultural organizations are eager to collaborate on research initiatives focused on agricultural data to enhance the agriculture sector. Microbial infections significantly impede the productivity of plants in horticulture (Huang et al. 2021). However, researchers must create a sustainable and economically efficient approach that prioritizes detecting and avoiding diseases to increase the quantity and quality of agricultural output using biotechnology. Computational approaches are becoming essential in identifying and understanding the outbreaks of diseases in cotton farms. AI-based tools have been developed to identify agricultural and horticulture diseases and overcome the challenges associated with manual processes (Thaiyalnayaki & Joseph 2021). The study explains the numerous computational approaches used at various stages of the plant-pathogen system. These methods are presented in terms of their advantages, limitations, and efficiency and are contrasted using assessment criteria. The extensive body of research conducted in the specialized area of automated detection of diseases in cotton fields from 2000 to 2023 is visually shown in Figure 4. A comprehensive evaluation of this study is provided, including a critical analysis. The graph clearly shows that the pinnacle of comprehensive and computerized cotton disease identification research will be reached in 2023.

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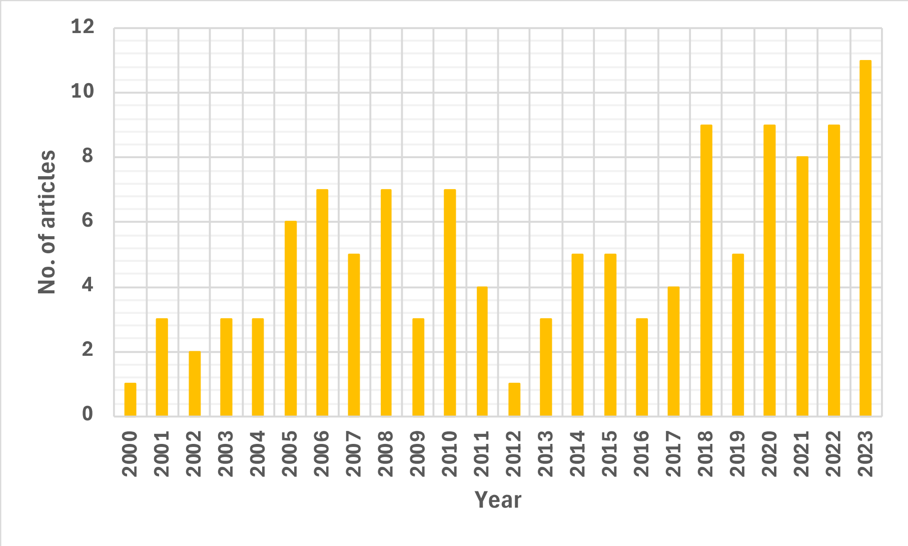

Figure 4. Article publication in the proposed topics

Figure 5 displays academics' various strategies at different computer-aided automatic cotton illness detection method phases. The authors emphasized the categorization step of the diagnostic procedure in cotton farms using biotechnology. The noise elements impact the image structure for farming information. Effective pre-processing methods are required to eliminate undesirable characteristics from photos and enhance images before the diagnosis of particular illnesses. This study found that the Gaussian and median filters are effective for pre-processing images of cotton plants. The pre-processing task is crucial for removing pollutants from cotton leaf pictures and preparing them for other operations, such as segmentation and extraction of features.

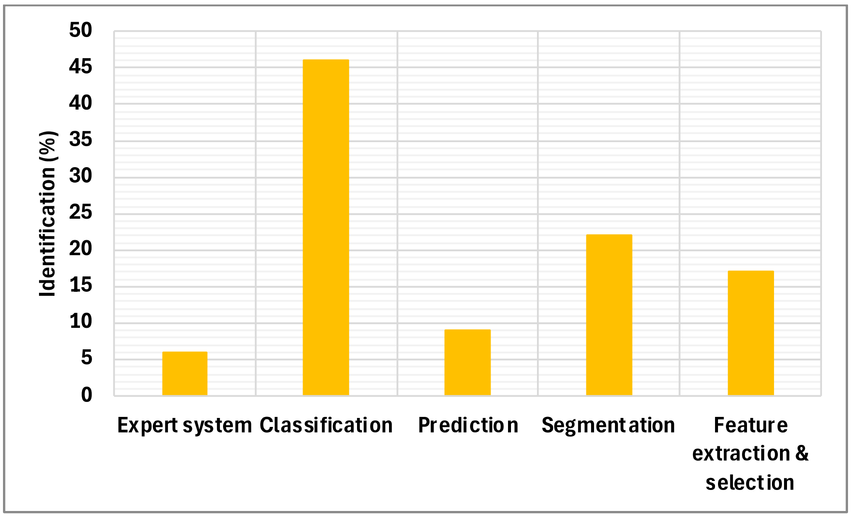

Figure 5. Identification results of different process

Conclusions: Agriculture is the foundation for global economic activities and has experienced several technical advancements and enhancements to produce higher-quality goods. Farmers allocate substantial financial resources towards managing cotton diseases, as inadequate disease control measures lead to significant economic losses without proper professional assistance using biotechnology (Divyanth et al. 2023). Plant diseases can wreak havoc on natural ecosystems and exacerbate environmental issues. Practical computational algorithms are advantageous for cotton plant diseases (Dong et al. 2021). This study presents many computer algorithms that analyze photos of cotton plants to extract crucial characteristics for disease diagnosis and draw diagnostic findings. The AI methods achieved superior results in classifying illnesses affecting cotton plants. AI has been highly successful in classifying cotton illnesses, demonstrating the effectiveness of AI in this field. Utilizing AI structures to detect diseases on cotton leaves facilitates efficient and accurate examination of cotton plants using biotechnology (Steinwand & Ronald 2020). This study examined the challenges encountered in each stage of the AI-aided method for identifying plant diseases in cotton leaves. These stages include pre-processing, RoI identification, extraction of features and choice, and classification. Based on this thorough examination of the research on automated diagnosis of cotton leaf illnesses, researchers can utilize it as a guide to create a future system that is effective, cost-effective, precise, and quick in identifying various diseases using photos of cotton plants using biotechnology. Moreover, in the future, this illness detection technology might be integrated into smartphone applications to alert the farmer once the infections have been identified promptly. The farmer can quickly react and hinder the propagation of the illness in the areas. This study aims to motivate young investigators to develop an AI-assisted method for analyzing cotton-diseased leaves to enhance cotton farming.

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دانشگاه شهید باهنر کرمان
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مانیش نندی

*نویسنده مسئول: استادیار، گروه علوم کامپیوتر و فناوری اطلاعات، دانشگاه کالینگا، رایپور، هند. آدرس پست الکترونیکی: ku.manishnandy@kalingauniversity.ac.in

آهیلیا دوبی

پژوهشگر، گروه علوم کامپیوتر و فناوری اطلاعات، دانشگاه کالینگا، رایپور، هند. آدرس پست الکترونیکی: ahilya.dubey@kalingauniversity.ac.in

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چکیده

هدف: پنبه یک الیاف برجسته است که بخش‌های صنعتی و کشاورزی در سراسر جهان را کنترل می‌کند. پنبه یک ماده اساسی است که در ساخت منسوجات استفاده می‌شود. تشخیص زودهنگام بیماری‌های روی برگ‌های پنبه برای پیشگیری از آنها و افزایش بهره‌وری ضروری است. ردیابی بیماری‌های برگ پنبه و ارزیابی سلامت گیاه برای کشاورزانی که صرفاً بر تخصص و دانش ذهنی خود متکی هستند چالش برانگیز است. علاوه بر این، شبکه‌های عصبی مصنوعی برای کاهش محدودیت‌های روش‌های سنتی پیشنهاد شده‌اند و می‌توانند برای مدیریت داده‌های غیرخطی و پیچیده، حتی زمانی که داده‌ها نادقیق و نویز هستند، استفاده شوند. داده های کشاورزی می توانند بسیار بزرگ و پیچیده باشند که از طریق تجزیه و تحلیل بصری یا همبستگی های آماری قابل رسیدگی نباشد. این امر استفاده از هوش ماشینی یا هوش مصنوعی را تشویق کرده است. هدف این مطالعه تشخیص بیماری‌ها و بهبود کشت پنبه با استفاده از روش‌های هوش مصنوعی (AI) بود.

نتایج: یافته‌های مطالعه نشان می‌دهد که روش‌های تشخیص خودکار فعلی برای بیماری‌های محصول پنبه هنوز در مراحل اولیه توسعه خود با بیوتکنولوژی و هوش مصنوعی (AI) هستند. این بررسی نیاز به توسعه ابزارهای تشخیصی خودکار، مقرون‌به‌صرفه، قابل اعتماد، دقیق و سریع را برای تشخیص بیماری‌های برگ پنبه برای افزایش بازده و کیفیت تأیید می‌کند.

نتیجه‌گیری: این مقاله چندین تکنیک محاسباتی مورد استفاده در مراحل مختلف ساختارهای بیماری‌زای گیاهی، از جمله آماده‌سازی تصویر، تقسیم‌بندی، استخراج ویژگی‌ها و انتخاب، و طبقه‌بندی را تحلیل می‌کند. این مطالعه مسیرها و مناطق معتبر آینده را برای اکتشاف بیشتر شناسایی کرد. برای شناسایی و دسته‌بندی بیماری‌های مختلف در محصولات پنبه به روش‌های نوآورانه و کاملاً خودکار به کمک رایانه نیاز است.

واژه‌های کلیدی: بیماری های پنبه، بیوتکنولوژی، محصول پنبه، هوش مصنوعی

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