International Journal of Science and Research Archive

eISSN: 2582-8185

Cross Ref DOI: 10.30574/ijsra

Journal homepage: https://ijsra.net/

(Review Article)

Check for updates

Review on Plant Parasitic Nematode (PPN) Infections in Sugarcane Cultivation Using AI Algorithms

Viswanathan Arjunan [1, 3] and Surya Prabha Deenan [2, *]

[1] Department of Computer Science, Nehru Arts and Science College, Thirumalayampalayam, Coimbatore – 641105, India.
[2] Department of Information Technology, Nehru Arts and Science College, Thirumalayampalayam, Coimbatore – 641105, India.
[3] Department of Computer Science, Islamiah College (Autonomous), Vaniyambadi, Tirupattur-635751.

International Journal of Science and Research Archive, 2025, 14(02), 430-441

Publication history: Received on 26 December 2024; revised on 02 February 2025; accepted on 05 February 2025

Article DOI: https://doi.org/10.30574/ijsra.2025.14.2.0366

Abstract

Sugarcane farming plays a vital role in India's economy, society, and culture, as the country is among the top producers and users of sugarcane globally. Plant parasitic nematodes (PPNs) is a major global threat to sugarcane crops, resulting in yield reductions and financial hardship for farmers. In order to minimize crop damage and implement efficient management strategies, the early detection of nematode infestations is imperative. Artificial Intelligence (AI) presents a viable approach for the early identification, tracking, and prevention of damage caused by nematodes through the implementation of cutting-edge machine learning algorithms, remote sensing technologies, and data analytics. This review focuses on the use of AI in sugarcane crop nematode infection detection and management. By integrating AI technologies in a complementary way with conventional agricultural practices, it is feasible to enhance the productivity and resistance of sugarcane crops to nematode infections.

Keywords: Artificial Intelligence (AI); Convolutional Neural Network (CNN); Image remote sensing; Machine Learning; Nematode; Sugarcane

1. Introduction

Sugarcane (Saccharum species) is a perennial grass hybrid, is the main crop grown in monocultures by the world's sugar industries [1]. Sugarcane alone is used to produce 75% of the sugar produced worldwide. India ranks second in terms of the production and consumption of sugar. Additionally, India has the second-largest agriculture-based economy [2, 3]. A monoculture of sugarcane can lead to pathogen pressure problems. Nematodes are regarded as one of these that pose the greatest obstacle. There has been a 20% reduction in crop production due to nematode damage in sugarcane culture. Additionally, nematodes may prevent new crops from being grown in infested areas, thus making certain crops in such areas uneconomical [4, 5].

In the animal kingdom, Nematoda constitutes one of the largest phyla, with a wide range of species and lifestyles. In the current state of knowledge, there are more than 25, 000 species of nematodes [6]. Approximately 50% of these dwells in marine saltwater and 25% in freshwater and soil [7]. There are over 4100 kinds of Plant parasitic nematodes (PPNs) known to date, which represent a major threat to global food security [8]. Nematode infections are often disregarded because they can be hard to treat and their symptoms may not always be noticeable. To effectively manage these plant parasites and preserve non-parasitic nematodes, accurate decision-making can be facilitated by nematode detection and differentiation [9]. The difficulty in distinguishing nematodes depends on a variety of factors, including the absence of specific morphological characteristics, the nematode's small size, and/or the high number of nematodes in the samples. These factors can potentially affect the performance of the identification assays.

* Corresponding author: Surya Prabha Deenan

Thus, developing a customized dataset is mainly driven by addressing the demands for a sugarcane disease identification system. Additionally, a thorough analysis of the trade-off between accuracy and several hyperparameters is conducted in order to determine the best option for a sugarcane disease identification system [10, 11]. The development of machine learning, also known as deep learning or artificial intelligence (AI), has provided a new method of identifying and quantifying nematodes based on image analysis. In complex backgrounds, the technique is particularly useful for detecting nematode eggs, for instance, in large quantities of samples. This review focuses on the use of AI in sugarcane crop nematode infection detection and management.

2. Review Methodology

This section describes the methodology for carrying out the investigation's systematic review and examines the ways in which computational techniques can be used to investigate sugarcane plant pathogens in a broader context. In this study, about 315 articles about plant diseases were downloaded after searching across multiple databases, including Elsevier, Web of Science, Scopus, ACM Digital Library, Wiley, Science Direct, PubMed, IEEE, Springer, and Google Scholar, were identified. The search is specifically limited to the years 2008 through 2024. The next step involved sorting out the pre-selected items and eliminating all duplicate and irrelevant investigations. Next, 63 papers pertinent to sugarcane diseases were selected for the systematic review of computational techniques applied to nematode infected sugarcane pathology. The procedure for selecting literature for the purpose of using computational methods to identify sugarcane disease is shown in Fig. 1. Additionally, an effort is made to identify any study limitations that would help us proceed with future research.

The research interrogations (RIs) are.

- What are the most common sugarcane diseases?
- Is nematode infection a problem in sugarcane cultivation, and how does it impact the plant?
- What AI tools have been developed for the detection of nematode-infected sugarcane diseases, and for other related concerns in the sugarcane industry?

The Keyword Search

The authors have employed the following inquiry keywords: ["Sugarcane Diseases"], ["Nematode Infection"], AND [" Nematode infection in Sugarcane Diseases using Machine learning", "Nematode infection in Sugarcane disease using Artificial Intelligence", OR "Nematode infection in Sugarcane diseases using Deep learning", OR "Nematode infection in Sugarcane disease using Image processing"]

2.1. Inclusion Criteria

- The Sugarcane (Root) must be the focus of research papers, which must also address any RIs.
- Studies implement the system using AI tools.
- Studies must have been written in the English language.
- Peer review is required for papers.
- Research contrasted prediction model performance.
- Documents ought not to be replicable.

2.2. Exclusion Criteria

- Studies that do not address any RIs and do not specifically target the sugarcane plant.
- Research not conducted with AI tools.
- Papers are not written in the English language.
- Papers that only include a portion of the length.
- Papers that are out of timeframe.
- Conference papers if they are published in a journal.

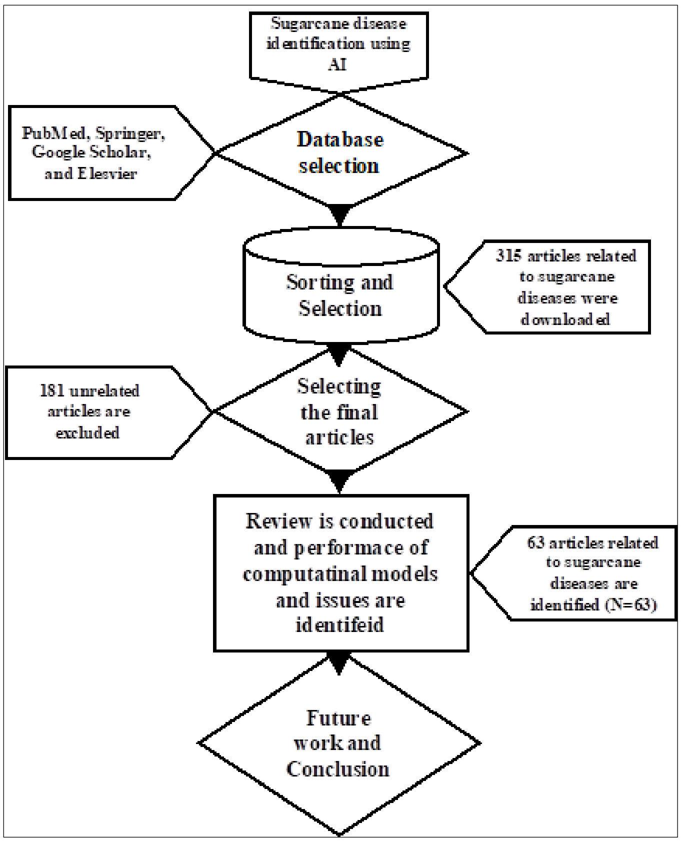

Figure 1 Flow Diagram of Literature Survey selection process

3. Result analysis

3.1. What are the most common sugarcane diseases?

Sugarcane (Saccharum spp.) is a unique agricultural plant that evolved from a wild grass species to a significant crop used for energy, food, and fodder via anthropogenic evolution. Moreover, it makes up around 70% of the world's sugar output and has enormous potential for producing biomass and ethanol-based biofuels. 2018 saw a total of 1,907,024,730 tons (190.7 million metric tons/MMT) of sugarcane produced worldwide, with Brazil and India leading the way [12]. Around 8000 BC, sugarcane was first domesticated in the New Guinea region, and later it spread to Southeast Asia and India. In the fifth century AD, an Indian scientist developed a unique method for crystallizing sugar that made it easier to store and transport the solidified sugar compounds. In the Poaceae family, sugarcane is a member of the Andropogoneae tribe and genus Saccharum. A group of closely related genera known as the Saccharum complex includes Miscanthus, Sclerostachya, Erianthus, Narenga, and Saccharum [13]. The interspecific hybrid that is domesticated sugarcane is polyploid, aneuploid, and vegetatively propagated; its estimated genome size is > 10 Gb. S. officinarum (80%), S. spontaneum (10–15%), and only a small proportion of recombinant chromosomes (5–10%) contributed significantly to the genome [12, 14, 15].

In the past century, the nation has had epidemics of rust, yellow leaf (YLD), red rot, smut, wilt, and scald. Depending on the kind of illness and how the affected types spread, different epidemics would cause different amounts of harm to sugarcane. India has reported on over fifty-five sugarcane diseases brought on by bacteria, viruses, nematodes, phytoplasmas, and fungi [16]. Table 1 enumerates the major sugarcane diseases that have been identified in India to date. Wilt and smut are the other two primary diseases that have a significant impact on India's cane production, with red rot continuing to be the predominant cause of sugarcane disease in the nation. Furthermore, cane productivity is seriously harmed by the emerging illness yellow leaf disease in many states. Pokkah boeng, rust, and grassy shoot disease severity are all increasing across the nation [16-20].

Table 1 Causative factors of sugarcane diseases

Sugarcane diseases		
Bacterial	**Fungal**	**Viral/ Parasitic**
Gumming (*Xanthomonas campestris pv.vasculorum* (Cobb) Dye) Leaf scald (Xanthomonas albilineans (Ashby) Dowson) Ratoon stunting (Leifsonia xyli subsp. xyli Davis et al.) Red stripe (Pseudomonas rubrilineans (Lee et al.) Stapp) Spindle rot (Pseudomonas rubrileneans pv. Spidulifoliens) Stinking rot (Pseudomonas desaiana (Burkholdre) Savulescu)	Red rot (*Colletotrichum falcatum Went*) Smut (*Sporosorium scitamineuma*) Wilt (*Fusarium sacchari*) Pineapple disease (*Ceratocystis paradoxa*) Pokkah boeng *(Giberella moniliformis, Fusarium moniliforme)* Rust *(Puccinia melanocephala, P. kuehnii)* Stalk rot (rind disease) *(Phaeocytostroma sacchari(Ell. & Ev.) B.Sutton)* Eye spot *(Bipolaris sacchari E. Butler (Shoemaker))* Brown spot *(Cercospora longipes)* Leaf scorch *(Stagonospora sacchari Lo & Ling)* Leaf-splitting disease *(Peronosclerospora miscanthi(T. Miyake) C.G.Shaw)* Periconia leaf spot *(Periconia atropurpurea, P. Saraswatipurensis)* Pestalotia leaf spot *(Pestalotia fuscescens Sor. var. sacchari)* Phyllosticta leaf spot *(Phyllosticta sorghina Sacc)* Red rot of leaf sheath *(Pellicularia rolfsii, Hypochnus centrifugus)* Red spot of leaf sheath *(Cercospora vaginae)* Schizophyllum rot *(Schizophyllum commune Fr)* Seeding blight *(Alternaria, curvularia, Drechslera, Cochliobolus)* Sheath rot (*Cytospora sacchari)* Sooty mould *(Capnodium sp., Fumago sacchari Speg*) Target blotch *(Helminthosporium sp.)*	Mosaic (*Sugarcane mosaic virus, Sugarcane streak mosaic virus*) Plant-parasitic nematodes (PPN) (*Pratylenchus spp, Meloidogyne spp*.).

3.2. Is nematode infection a problem in sugarcane cultivation, and how does it impact the plant?

3.2.1. Nematode Infection in Sugarcane

Sugarcane belongs to the family Gramineae, class monocotyledons, order glumaceae, subfamily panicoidae, tribe andripogoneae, and subtribe saccharinin [21, 22]. It is widely utilized to make jaggery, white sugar, and other byproducts such as bagasse and molasses due to its high sucrose content [3]. Indian sugar, the world's second-largest industry, supports rural development and the nation's economy. Sugarcane contributes 1.1% to the national GDP despite being grown on only 2.57 percent of gross cropland [23]. The sugar industry is preparing for the challenges of 2030 by diversifying, judiciously integrating agro-technology, improving management techniques, and enacting policies that assist farmers. In addition to meeting the nation's needs for food and energy, the crop promotes social development, environmental safety, and the creation of jobs and income. Sugarcane cultivation will continue to play a significant role in the sustainable growth of the sugar industry in India due to the crop's numerous benefits and versatility [24]. Over the past century, the nation has experienced epidemics of rust, yellow leaf (YLD), red rot, smut, wilt, and scald. Each epidemic causes different damage to sugarcane, depending on the type of disease and how the affected varieties spread. Many sugarcane varieties were replaced as a result of new pathogenic strains or diseases breaking down in them [17].

The existence of plant-parasitic nematodes (PPNs) is one of the factors affecting production, despite the sugarcane's increasing area and productivity since recent crop yields. Numerous species of these pathogens have a detrimental effect on crops in almost every part of the world where sugarcane is planted. A global average of 20% is thought to be lost annually due to the more than 300 species of plant-parasitic nematodes that are found in 48 genera and are linked to sugarcane crops [25]. But the extent of the damage might differ based on the species involved, their population sizes, the sugarcane variety's susceptibility, and the year's cropping season [26]. Plant-parasitic nematodes became more abundant as crops developed, but their taxonomic diversity declined [27, 28]. There are numerous species of PPN, but the two most significant ones for sugarcane are the lesion nematode (Pratylenchus spp.) and the root-knot nematode (Meloidogyne spp.). Additional nematodes that harm the economy are the stubby root nematode (Paratrichodorus minor), dagger nematode (Xiphinema spp.), and stunt nematode (Tylenchorhynchus annulatus). Spiral nematodes (Helicotylenchus dihestera) and reniform nematodes (Rotylenchulus spp.) only become economically destructive when populations are high enough. The most significant species of RKNs are (i) Meloidogyne spp., which also includes M. incognita, M. chitwoodi, M. enterolobii, and M. graminicola; (ii) the nematodes that form cysts in the genera Globodera and Heterodera, which include the PCNs Globodera rostochiensis and G. pallida, as well as the Heterodera avenae group, H. ciceri, H. glycines, and H. schachtii [29-31].

There are at least five distinct species of plant-parasitic nematodes in every sugarcane field, and they are extensively distributed in soils used for sugarcane growth. Climate, soil type, and crop history all affect the number and proportion of different species. A study published recently revealed that eight phytonematode species have been identified, including Xiphinema setariae, Pratylenchus zeae, Rotylenchulus reniformis, Hoplolaimus indicus, Criconemoides morgenensis, Coslenchus paramaritus, Helicotylenchus sp. and Tylenchus sp. The most abundant species found in sugarcane roots was Pratylenchus zeae [32]. While nematodes known to cause lesions can be found in any cane field, nematodes known to cause knotting in roots are primarily found in lighter. Since nematodes have limited life cycles—as minimal as 4-5 weeks in warm climates—populations can grow rapidly (Figure 2). If it pertains to lesion nematodes, adult females deposit hundreds of eggs in the soil, on the exterior of the roots, or both. For root knot nematodes, the eggs are laid on the roots. After hatching, juveniles go through four moults. The natural discharges of the host plant roots draw adult organisms that propagate slowly through the soil [33]. While their eggs may lie dormant in the soil for several months, plant parasitic nematodes need live plant roots as a food source to finish their life cycle [34]. While most other nematodes feed on the outside of the roots, RKNs and lesion nematodes enter the root tips. Depending on the species present, damage to the roots will vary. On the other hand, lesion nematode, or the abundance of red lesions on the tips of the roots, and short, thickened, and blackened primary roots with very few fine secondary or tertiary roots are typical symptoms [35]. There could be an obvious primary root overbranching. In the event that RKNs are present, swollen galls on the roots may be seen [36]. Nematode-damaged root systems leave them vulnerable to additional bacterial and fungal invasions [37, 38].

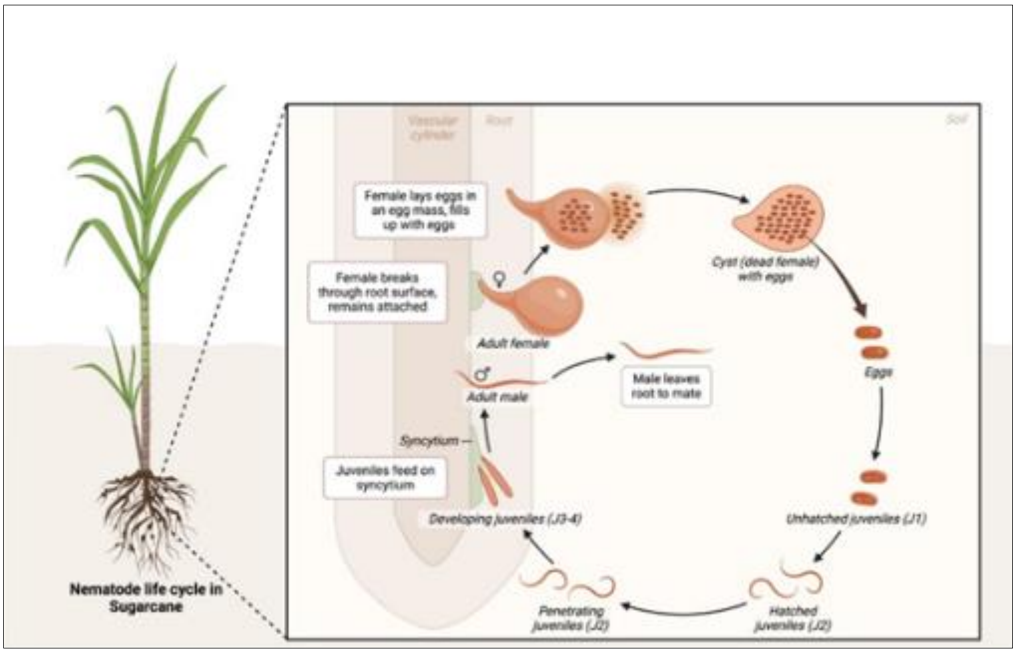

Figure 2 Nematode life cycle in sugarcane plant

3.3. What AI tools have been developed for the detection of nematode-infected sugarcane diseases, and for other related concerns in the sugarcane industry?

3.3.1. AI in Nematode Infection

As technology advances, artificial intelligence (AI) fields such as machine learning (ML) and deep learning (DL) are proving to be promising fields for improving various aspects of agricultural practices, including the production of sugarcane crops and the identification of diseases affecting sugarcane crops [11]. Several AI technologies, including artificial neural networks (ANNs), can enhance sugarcane crop production by collecting and analyzing diverse sugarcane diseases in a variety of ways. A number of recent studies have demonstrated the potential of machine learning and deep learning to enhance sugarcane production [39, 40]. These include the prediction of crop yields, the determination of soil agricultural aptitude, weed identification, and the classification of sugarcane varieties. ANNs, in particular, are promising tools for modelling sugarcane cultures, suggesting their potential for helping optimize sugarcane production and identify sugarcane diseases [41, 42]. Table 2 described the AI application in identification of sugarcane diseases.

An early application of artificial intelligence was used in the early years of 1996 when image analysis systems were first developed as a means of assisting with nematode analysis by counting nematodes in a suspension or by automatically recognizing nematodes as part of a detection process. Furthermore, computerized keys can help identify different species [43]. A study by Omarjee et al revealed a positive relationship between Burkholderia populations and plant feeding nematodes, H. dihystera, P. zeae, and B. tropica in sugarcane using Principle Component Analysis (ADE-4) [44]. Luana et al. used the vegan package in R version 3.2.3 to analyze the relationships between nematode population densities and plant parameters. The RDA reported that Meloidogyne abundance increased with potassium content. There was an association between Pratylenchus's low phosphorus content and its large stalk diameter [45]. The body of research explicitly addressing using AI to manage nematode-related diseases in sugarcane is still quite small, despite the growing interest in applying AI to agricultural concerns. Though there aren't many research publications available for this specialized application, there aren't many in-depth insights. As such, the present section on the use of AI in nematode management in sugarcane agriculture must be succinct. Existing AI research in agriculture has largely targeted more commonly studied crops and pests. For instance, studies on AI-driven pest detection in crops like tomatoes and wheat provide insights that could be extrapolated to sugarcane. The paucity of research impedes the creation of all-encompassing AI-based approaches, exposing a significant vacuum in the literature and providing a chance for further investigation into this area of AI and agricultural pathology.

Table 2 AI applications in sugarcane diseases

S.No	Diseases	AI Model	Inference	References
1	Sugarcane leaves diseases	Attention-based multi-level residual convolutional neural network (AMRCNN)	AMRCNN outperformed state-of-the VGGNet, ResNet, XceptionNet, and EfficientNet models with a classification accuracy of 86.53%.	[27]
2	Sugarcane smut and Pachymetra root rots	Genomic best linear unbiased prediction (GBLUP), including extensions to model dominance and epistasis, Bayesian methods including BayesC and BayesR, Machine learning methods including random forest, multilayer perceptron (MLP), modified convolutional neural network (CNN) and attention networks designed to capture epistasis across the genome-wide markers.	The Bayesian methods (BayesR and BayesC) gave the highest accuracy of prediction, followed closely by hybrid methods with attention networks.	[46]
3	Sugarcane leaves diseases	CNN	SVM, random forest, and CNN to classify sugarcane leaf	[47]

			diseases based on color, texture, and shape features.	
4	Eyespot, Leaf Scald, Yellow Leaf, and Pokkah Boeng	ANN, Neuro-Fuzzy, and Case-Based Reasoning (CBR) algorithms by feature extraction technique	Three characteristics such as color, shape, and texture were evaluated in terms of sensitivity, specificity, F1 score, and accuracy.	[48]
5	Leaf diseases	Hybrid optimal machine learning technique (HOML-SL). non-linear cluster-based optimization (NCO) algorithm, cross layer optimization (CLO) algorithm, Moth flame based capsule neural network (MFO-CNN) algorithm	HOML-SL disease detection can compare with the accessible state-of-art detection techniques in terms of accuracy, precession, F-measure and Recall.	[49]
6	Sugarcane red rot disease	A multi-layer perceptron (MP) based DL model	Achieved an accuracy rate of 97.97% for binary classification and an accuracy rate of 98.03% for overall multi-classification.	[50]
7	Brown stripe and Ring spot diseases	Modified flower pollination algorithm (MFPA) and SVM	The developed simplified SVM model, which utilized the MFPA wavelength selection method yielded the best performances, achieving a precision value of 0.9753, a sensitivity value of 0.9259, a specificity value of 0.9524, and an accuracy of 0.9487.	[51]
8	Leaf diseases	InceptionV4, VGG16, ResnetV2-152, and AlexNet	DL algorithms models classifying sugarcane leaf diseases at 99.61 accuracy.	[52]
9	White Leaf Disease	UAV-Derived RGB Imagery DL(YOLOv5, YOLOR, DETR, and Faster R-CNN	YOLOv5 is recommended for detecting WLD using the UAV data because it was the smallest model chosen (14 MB).	[53]
10	Sugarcane – Non sugarcane classification	Long short-term memory (LSTM) neural network (ptical and SAR time-series analysis)	High accuracy than original dataset	[54]
11	Grassy shoot disease, Smut disease, Black rot disease	CNN	CNN with four discrete classes, the analysis shows an accuracy of 98.69% for sugarcane disease detection.	[55]
12	Water deficits	CNN (*Inception-Resnet-v2* network)	Using non-destructive methods to categorize the water stress of thermal images of plants.	[56]
13	Infections	YOLO and Faster R-CNN	Identifying complex patterns and variations	[57]

14	Leaf scald, Mottled stripe, Red stripe (top rot), Black, Schizophyllum rot	Inception v3, VGG-16 and VGG-19	Sugarcane disease analyzing byits laves, stem, color. AUC (90.2%accuracy) and sensitivity are calculated using Orange software	[3]
15	Sugarcane brown rust resistance	K-nearest neighbor (KNN), SVM, Gaussian process (GP), decision tree (DT), random forest (RF), multilayer perceptron (MLP) neural network, adaptive boosting (AB), and Gaussian naive Bayes (GNB) implemented in the scikit-learn v.0.19.0 Python v.3 module.	Achieved an accuracy of up to 95% with a dataset of 131 SNPs related to brown rust QTL regions and auxiliary genes.	[58]
16	Leaf diseases	Image processing. of Adaptive Histogram Equalization (AHE), Gray Level Co-occurrence Matrix (GLCM), Principal Component Analysis (PCA), SVM	The average accuracy value is 95%.	[59]
17	Leaf diseases	CNN	StridedNet (90.10%), LeNet (93.65%), and VGGNet (95.40%) accuracy rate shown.	[60]
18	Leaf diseases	CNN	DL model consisting of 13,842 sugarcane image dataset of disease infected leaves and healthy leaves achieving an accuracy of 95%.	[61]
19	sugarcane borer diseases	SVM (support vector machine)	The RBF kernel function can be used as the kernel function of the SVM to solve the problem of sugarcane borer disease detection	[62]
20	Bacterial, Viral diseases, Fungal diseases, Phytoplasma diseases, Nematodes, parasitic and other miscellaneousdiseases and disorders	Decision Tree Model (DTM) method and Random Forest method	Crop yield disease calculation	[63]

3.3.2. Limitations and Future perspectives

Plant-parasitic nematodes, or PPNs, are one of the most well-known and underestimated hazards to plant health and food security in the world. It can decimate crops and result in losses worth billions of dollars every year. Research in this field is hampered by a number of issues. Important gaps include the dearth of thorough datasets dedicated to sugarcane nematodes, the slow progress of creating AI models for this issue, and the difficulty of field-validating AI solutions. Furthermore, developing precise prediction models is made more difficult by the complex life cycle and behavior of nematodes. The application of AI in sugarcane has immense potential to combat nematode infection; however, in order to effectively implement this prospect and advance resilient and sustainable sugarcane cultivation, it will be necessary to overcome current challenges and embrace innovative concepts.

3.3.3. The current challenges are,

- Data Availability : The lack of thorough and superior data is one of the main obstacles to using AI to treat nematode infections in sugarcane. Insufficient datasets could impede the creation and verification of AI models, thereby affecting their precision and dependability.

- Cost and Infrastructure : The adoption of AI technologies necessitates substantial expenditures in computing power, technical assistance, and infrastructure. These costs may be prohibitive, particularly for farming communities with limited resources. Ensuring the infrastructure is available and solving cost-effectiveness problems are essential for the long-term implementation of AI solutions.
- Scalability : Although solutions that use AI appear promising, scalability is still a problem, especially in small-scale farming communities where assets such as technology may be scarce. For AI applications to be widely adopted, it is imperative that they be scalable across various agricultural fields and socio-economic contexts.

3.3.4. Future perspectives are,

- Developments in Remote Sensing and Sensing Technologies: The identification and tracking of nematode outbreaks in sugarcane crops may be improved with ongoing advances in remote sensing technologies, which include drones, IoT sensors, and satellite imagery. AI algorithms that are integrated with these technologies may facilitate decisive management techniques and offer real-time insights.
- Data Integration and Sharing : To enable the creation of reliable AI models for the control of nematode infections in sugarcane, future research endeavors ought to concentrate on improving data integration and sharing protocols. Model performance can be enhanced by overcoming data limitations through partnership efforts and data-sharing platforms.
- Capacity Building and Extension Services: Investing in initiatives aimed at building capacity and providing extension services is crucial to equipping farmers with the necessary knowledge and abilities to effectively utilize AI-based solutions. Programs for farmer learning, technical assistance, and education can encourage the uptake of AI tools and promise their enduring application.
- Adoption of Precision Agriculture Techniques: AI tools may redefine sugarcane cultivation by facilitating the implementation of precision agriculture techniques, which can transform nematode infectios management. Optimizing resource use efficiency and minimizing adverse ecological effects can be achieved through location-specific strategies for management focused on treatments and precise utilization of inputs.

Development and validation of AI models tailored to sugarcane nematode management should be the main focus of future research. Data scientists, AI specialists, and agronomists working together interdisciplinary will be essential. Progress in these understudied issues will also be accelerated by obtaining financing for thorough investigations and field tests

4. Conclusion

Nematode infection in sugarcane is an outbreak in agriculture that can result in significant monetary losses and jeopardize global food security. To lessen the effects on sugarcane cultivation, nematode infestations must be promptly detected and effectively managed. Applications of AI present viable answers to this challenge by providing modern tools for the early diagnosis, tracking, and treatment of nematode infections in sugarcane crops. AI-powered systems can also expedite breeding programs targeted at improving nematode resistance and aid in cultivating resistant sugarcane cultivars through genetic analysis. But to guarantee the availability, cost-effectiveness, and scalability of artificial intelligence (AI) tools in sugarcane agriculture, partnerships between researchers, agronomists, legislators, and farmers are necessary for effective deployment.

Furthermore, farmers can obtain cutting-edge knowledge about nematode infections by integrating AI tools such as ML algorithms, remote sensing, and data analytics, which allow for early decision-making and precise therapeutic approaches. The potential advantages of using AI to treat nematode diseases in sugarcane are significant, notwithstanding the paucity of research currently available in this area. Through focused study, the gaps that now exist will be filled, leading to creative solutions that will improve the production and sustainability of sugarcane. In order to fully utilize AI in agriculture, it is essential that the scientific community give this field top priority. Nematode outbreaks can be anticipated via AI-driven predictive models, which enable farmers to allocate resources more efficiently and initiate preventative action. In summary, the use of AI in the management of nematode infections presents a revolutionary strategy for protecting sugarcane crops, maintaining agricultural livelihoods, and guaranteeing food security in areas heavily dependent on sugarcane farming. Sugarcane crops can be made more resilient and productive against nematode infections by combining AI with conventional agricultural methods in a synergistic way.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Berry, S.D., et al., Detection and quantification of root-knot nematode (Meloidogyne javanica), lesion nematode (Pratylenchus zeae) and dagger nematode (Xiphinema elongatum) parasites of sugarcane using real-time PCR. Molecular and Cellular Probes, 2008. 22(3): p. 168-176.

[2] Daphal, S.D. and S.M. Koli, Enhancing sugarcane disease classification with ensemble deep learning: A comparative study with transfer learning techniques. Heliyon, 2023. 9(8).

[3] Srivastava, S., et al., A novel deep learning framework approach for sugarcane disease detection. SN Computer Science, 2020. 1: p. 1-7.

[4] Kumbhare, S.T., et al., DETECTION AND CLASSIFICATION OF DISEASES ON RICE AND SUGARCANE USING COMPUTER VISION TECHNIQUE. IJRAR-International Journal of Research and Analytical Reviews (IJRAR), 2019. 6(2): p. 79-84-79-84.

[5] Dinardo-Miranda, L.L., et al., Biological control of phytoparasitic nematodes in sugarcane fields. Pesquisa Agropecuária Tropical, 2022. 52: p. e73758.

[6] Lu, M.R., et al., Comparative transcriptomics across nematode life cycles reveal gene expression conservation and correlated evolution in adjacent developmental stages. Genome biology and evolution, 2020. 12(7): p. 1019-1030.

[7] Lazarova, S., et al., Functional diversity of soil nematodes in relation to the impact of agriculture—a review. Diversity, 2021. 13(2): p. 64.

[8] Shao, H., et al., Current advances in the identification of plant nematode diseases: From lab assays to in-field diagnostics. Frontiers in Plant Science, 2023. 14: p. 1106784.

[9] Morgado, T.D.T., et al., Effectiveness and persistence of biological control of nematodes in sugarcane. African journal of agricultural research, 2015. 10(49): p. 4490-4495.

[10] Patil, S.B. and S.K. Bodhe, Leaf disease severity measurement using image processing. International Journal of Engineering and Technology, 2011. 3(5): p. 297-301.

[11] Oliveira, A.L., et al., Unraveling Biotic and Abiotic Factors Shaping Sugarcane Straw Polyphenolic Richness: A Gateway to Artificial Intelligence-Driven Crop Management. Antioxidants, 2023. 13(1): p. 47.

[12] Dinesh Babu, K.S., et al., A short review on sugarcane: its domestication, molecular manipulations and future perspectives. Genetic Resources and Crop Evolution, 2022. 69(8): p. 2623-2643.

[13] Singels, A., P. Jackson, and G. Inman-Bamber, Sugarcane, in Crop physiology case histories for major crops. 2021, Elsevier. p. 674-713.

[14] Garsmeur, O., et al., A mosaic monoploid reference sequence for the highly complex genome of sugarcane. Nature communications, 2018. 9(1): p. 2638.

[15] Zhang, J., et al., Allele-defined genome of the autopolyploid sugarcane Saccharum spontaneum L. Nature genetics, 2018. 50(11): p. 1565-1573.

[16] Thite, S., et al., Sugarcane Leaf Dataset: A Dataset for Disease Detection and Classification for Machine Learning Applications. Data in Brief, 2024: p. 110268.

[17] Viswanathan, R. and G. Rao, Disease scenario and management of major sugarcane diseases in India. Sugar Tech, 2011. 13: p. 336-353.

[18] Rajput, M.A., et al., Sugarcane smut: Current knowledge and the way forward for management. Journal of Fungi, 2021. 7(12): p. 1095.

[19] Lu, G., et al., Sugarcane mosaic disease: Characteristics, identification and control. Microorganisms, 2021. 9(9): p. 1984.

[20] Racedo, J., et al., Biotechnological Strategies Adopted for Sugarcane Disease Management in Tucumán, Argentina. Plants, 2023. 12(23): p. 3994.

[21] Kumar, P., et al., Efficient classification of sugarcane genomes. Journal of Pharmacognosy and Phytochemistry, 2021. 10(1S): p. 227-232.

[22] Moore, P.H., A.H. Paterson, and T. Tew, Sugarcane: the crop, the plant, and domestication. Sugarcane: physiology, biochemistry, and functional biology, 2013: p. 1-17.

[23] Solomon, S., Sugarcane production and development of sugar industry in India. Sugar Tech, 2016. 18(6): p. 588-602.

[24] Mishra, P., et al., Modeling and forecasting of sugarcane production in India. Sugar tech, 2021. 23(6): p. 1317-1324.

[25] Bellé, C., et al., Impact of different Meloidogyne species on the development of sugarcane plants. Anais da Academia Brasileira de Ciências, 2024. 96(1): p. e20200004.

[26] Singh, P.R. and A. Hajihassani, A taxonomic update on Tylenchorhynchus annulatus (Nematoda: Dolichodoridae), a widely distributed stunt nematode species. Nematology, 2024. 26(3): p. 341-349.

[27] Daphal, S.D. and S.M. Koli, Enhanced deep learning technique for sugarcane leaf disease classification and mobile application integration. Heliyon, 2024. 10(8): p. e29438.

[28] Maranhão, S.R., et al., Nematode abundance and diversity in sugarcane fields in Brazil. Tropical Plant Pathology, 2018. 43: p. 485-498.

[29] Greco, N., Detection of Resistance, Susceptibility, Tolerance, and Virulence in Plant–Nematode Interactions: Part II: Migratory and Semi-endoparasitic Nematodes, in Plant-Nematode Interactions. 2024, Springer. p. 171-226.

[30] Greco, N. and R.N. Inserra, Detection of Resistance, Susceptibility, Tolerance, and Virulence in Plant–Nematode Interactions: Part I—Sedentary Endoparasitic Nematodes, in Plant-Nematode Interactions. 2024, Springer. p. 103-169.

[31] Westerdahl, B., et al., Nematode problems in sugarcane and sugar beet and their sustainable management, in Nematode Diseases of Crops and their Sustainable Management. 2023, Elsevier. p. 565-594.

[32] Ramadhani, R., T. Damayanti, and L. Putra. The phytonematodes species on sugarcane plants (Saccharum officinarum L.) at Subang Sugar Factory PT PG Rajawali II, West Java. in IOP Conference Series: Earth and Environmental Science. 2022. IOP Publishing.

[33] Casteliani, A., et al., Behavioral aspects of Sphenophorus levis (Coleoptera: Curculionidae), damage to sugarcane and its natural infection by Steinernema carpocapsae (Nematoda: Rhabditidae). Crop Protection, 2020. 137: p. 105262.

[34] Kisaakye, J., et al., Chitin-enriched insect frass fertilizer as a biorational alternative for root-knot nematode (Meloidogyne incognita) management. Frontiers in Plant Science, 2024. 15: p. 1361739.

[35] Grifaldo-Alcantara, P.F., et al., Steinernema ralatorei n. sp. 1 Isolated from Sugarcane Areas at Veracruz, Mexico. Southwestern Entomologist, 2017. 42(1): p. 171-190.

[36] Escobar, C., et al., Overview of root-knot nematodes and giant cells, in Advances in botanical research. 2015, Elsevier. p. 1-32.

[37] Subedi, S., B. Thapa, and J. Shrestha, Root-knot nematode (Meloidogyne incognita) and its management: a review. 2020.

[38] Collange, B., et al., Root-knot nematode (Meloidogyne) management in vegetable crop production: The challenge of an agronomic system analysis. Crop protection, 2011. 30(10): p. 1251-1262.

[39] Bannerjee, G., et al., Artificial intelligence in agriculture: A literature survey. international Journal of Scientific Research in computer Science applications and Management Studies, 2018. 7(3): p. 1-6.

[40] Zielińska, S. and E. Kępczyńska, Neural modeling of plant tissue cultures: a review. BioTechnologia, 2013.

[41] Malabadi, R.B., et al., Cannabis sativa: applications of artificial intelligence and plant tissue culture for micropropagation. International Journal of Research and Innovations in Applied Science (IJRIAS), 2023. 8(6): p. 117-142.

[42] Kai, P.M., B.M. de Oliveira, and R.M. da Costa, Deep learning-based method for classification of sugarcane varieties. Agronomy, 2022. 12(11): p. 2722.

[43] Sikora, R.A., Coyne, D., Hallmann, J., & Timper, P. (Eds.), Plant parasitic nematodes in subtropical and tropical agriculture. CABI, 2018(978-1-78639-125-4).

[44] Omarjee, J., et al., Relationships between Burkholderia populations and plant parasitic nematodes in sugarcane. Applied Soil Ecology, 2008. 39(1): p. 1-14.

[45] da Silva, L.M.A., et al., Seasonal variation of plant-parasitic nematodes and relationship with nutritional and growth properties of sugarcane plantations. Tropical plant pathology, 2017. 42: p. 132-136.

[46] Chen, C., et al., Genomic prediction for sugarcane diseases including hybrid Bayesian-machine learning approaches. Frontiers in Plant Science, 2024. 15: p. 1398903.

[47] Santhrupth, B., Intelligent Disease Detection in Sugarcane Plants: A Comparative Analysis of Machine Learning Models for Classification and Diagnosis. International Journal of Intelligent Systems and Applications in Engineering, 2024. 12(8s): p. 299-306.

[48] Atheeswaran, A., et al., Expert system for smart farming for diagnosis of sugarcane diseases using machine learning. Computers and Electrical Engineering, 2023. 109: p. 108739.

[49] Selvakumar, V., HOML-SL: IoT based early disease detection and prediction for sugarcane leaf using hybrid optimal machine learning technique. Journal of Survey in Fisheries Sciences, 2023. 10(2S): p. 3284-3309.

[50] Brar, S.K., et al. Sugar Learning: Deep Learning for Rapid Detection and Classification of Sugarcane Diseases. in 2023 World Conference on Communication & Computing (WCONF). 2023.

[51] Ong, P., et al., New approach for sugarcane disease recognition through visible and near-infrared spectroscopy and a modified wavelength selection method using machine learning models. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, 2023. 302: p. 123037.

[52] Hernandez, A.A., J.L. Bombasi, and A.C. Lagman. Classification of sugarcane leaf disease using deep learning algorithms. in 2022 IEEE 13th Control and System Graduate Research Colloquium (ICSGRC). 2022. IEEE.

[53] Amarasingam, N., et al., Detection of White Leaf Disease in Sugarcane Crops Using UAV-Derived RGB Imagery with Existing Deep Learning Models. Remote Sensing, 2022. 14(23): p. 6137.

[54] Sreedhar, R., A. Varshney, and M. Dhanya, Sugarcane crop classification using time series analysis of optical and SAR sentinel images: a deep learning approach. Remote Sensing Letters, 2022. 13(8): p. 812-821.

[55] Upadhye, S.A., M.R. Dhanvijay, and S.M. Patil. Sugarcane Disease Detection Using CNN-Deep Learning Method. in 2022 Fourth International Conference on Emerging Research in Electronics, Computer Science and Technology (ICERECT). 2022.

[56] de Melo, L.L., et al., Deep learning for identification of water deficits in sugarcane based on thermal images. Agricultural Water Management, 2022. 272: p. 107820.

[57] Malik, H.S., et al. Disease recognition in sugarcane crop using deep learning. in Advances in Artificial Intelligence and Data Engineering: Select Proceedings of AIDE 2019. 2021. Springer.

[58] Aono, A.H., et al., Machine learning approaches reveal genomic regions associated with sugarcane brown rust resistance. Scientific reports, 2020. 10(1): p. 20057.

[59] Thilagavathi, K., et al., Detection of diseases in sugarcane using image processing techniques. Bioscience Biotechnology Research Communications, Special Issue, 2020(11): p. 109-115.

[60] Militante, S.V. and B.D. Gerardo. Detecting sugarcane diseases through adaptive deep learning models of convolutional neural network. in 2019 IEEE 6th International Conference on Engineering Technologies and Applied Sciences (ICETAS). 2019. IEEE.

[61] Militante, S.V., B.D. Gerardo, and R.P. Medina. Sugarcane disease recognition using deep learning. in 2019 IEEE Eurasia conference on IOT, communication and engineering (ECICE). 2019. IEEE.

[62] Huang, T., et al., Detecting sugarcane borer diseases using support vector machine. Information processing in agriculture, 2018. 5(1): p. 74-82.

[63] Beulah, R. and M. Punithavalli. Prediction of sugarcane diseases using data mining techniques. in 2016 IEEE International Conference on Advances in Computer Applications (ICACA). 2016. IEEE.