REVIEW OF STUDY ON ARTIFICIAL INTELLIGENCE USED IN INSECT, PEST MONITORING AND MANAGEMENT IN VIDARBHA'S COTTON CROPPING SYSTEMS

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Abstract
Vidarbha region in Maharashtra dependent on agriculture and allied activities near about all districts of Vidarbha are primarily cotton growing.Cotton yield primarily depends on weather, pest, insect, diseases and management practices.Artificial Intelligence (AI) has rapidly emerged as a trans-formative technology in agriculture, offering innovative solutions.The present review study pointed out that recommended improved integrated management of pest and insect along with larvae, application of Artificial Intelligence to enhance productivity, sustainability, and efficiency.addressing concerns related to privacy, crop management, and environmental protection.
***Keywords**: Vidarbha, Artificial Intelligence, integrated, crop management.*

Introduction

Vidarbha region in Maharashtra comprises 11 districts viz. Yavatmal, Akola, Amravati, Wardha, Buldhana, Washim, Nagpur, Chandrapur, Bhandara, Gadchiroli and Gondia This region has, for various reasons, remained backward industrially as well as agriculturally. Livelihood of around 65% rural population of this region is dependent on agriculture and allied activities. However, agriculture in this region is comparatively less productive than the State and National averages. Cotton is the most important cash crop of western Vidarbha region. Eight of eleven districts of Vidarbha are primarily cotton growing. Cotton farming is the backbone of the farmers of Yavatmal, Akola, Amravati, Wardha, Buldhana and Washim districts of western Vidarbha. An estimated 12 lakh ha is under cotton production in Vidarbha.

In Vidarbha region, cotton is the most important cash crop and cultivates more than 50.00 per cent cotton area of Maharashtra. Although India stands first in acreage of cotton however the yield is well below the other cotton growing countries. Cotton yield primarily depends on weather, pest, diseases and management practices. Among the several factors that are responsible for the low productivity of cotton in India, the damage caused by insect pests is the major limiting factor. As many as 1326 species of insect pests have been reported on this crop through the world. Also, cotton is subject to severe damage by 162 spp. of pests right from germination to the final picking. (1)

Artificial Intelligence (AI) has rapidly emerged as a trans-formative technology in agriculture, offering innovative solutions to enhance productivity, sustainability, and efficiency. This comprehensive review examines the role of AI in various agricultural practices, including precision farming, crop management, soil health monitoring, pest control, and predictive analytic. By leveraging AI-driven technologies such as machine learning, computer vision, and data analytic, farmers can make data-informed decisions to optimize resource usage, reduce input costs, and minimize environmental impacts.AI-driven technologies, particularly those with integrating computer vision, deep learning and machine learning also, offer automated and accurate identification of pests and insects, minimizing the misuse of chemical inputs and reducing ecological damage.

Review of literature:- Now a days most advanced phase in the development of AI-based insect pest monitoring in India involves integrating IoT, remote sensing, cloud computing and edge AI technologies phase marks a shift from static, post-hoc analysis to real-time, automated and continuous pest surveillance systems. Smart traps equipped with cameras and sensors have been developed to monitor nocturnal pests, including T. absoluta, H. armigera and S. litura. These devices are equipped with solar-powered units, GSM (Global System for Mobile Communications)/4G modules and low-power microcontrollers (e.g., Raspberry Pi, Arduino) that can run deep learning models, such as YOLOv5 or MobileNet, directly on the device. These edge AI models can detect, classify and count pest species instantly without relying on cloud servers, making them particularly useful in remote or rural agricultural areas with limited internet connectivity. IoT and sensor-based insect pest detection: IoT devices, such as mobile phones, drones and robots, along with AI algorithms, monitor pest activity in agricultural fields. These detect and count the insects caught on the traps. These tools help farmers make decisions about pest management by providing real-time data on insect pests (2). Sensors are devices that can detect and convert chemical and physical cues of a living organism into a format that a computer can analyze. They can gather information by taking pictures using cameras, recording sounds using microphones, measuring distance using LiDAR and radar sensors (03). ML is frequently used to train AI systems to read sensor data and make decisions based on it (3). Sensors combined with AI, ML and DL models are effective in detecting insect pests and advising control measures (4). On the other hand, acoustic sensors are integrated into insect traps to detect insects based on acoustic sounds. For example, Acoustic sensors, PID sensors, algorithms like LPC, FFT, STFT and Welch method, as well as the Chebyshev filter integrated with traps showed 99.78 % accuracy, 99.64 % specificity, 99.91 % sensitivity and 99.85 % precision for sound detection of 800 pests when compared to pre- trained models like YOLOv5, VG-16, DenseNet and ResNet-50, the Multilayer Perceptron (MLP)(5)

Remote sensing enabled AI for insect pest detection: Remote sensing technologies rely on receiving and interpreting information about the Earth's surface without any physical contact.(6)Electromagnetic energy is the core component of remote sensing. Various sensors were used to record electromagnetic radiation from the Earth's surface. Sensor instruments include digital cameras, electromechanical scanners, video cameras andradar devices.(7) For successful management of insect pests, forecasting is an important step that should be followed. It can be accomplished on smaller land areas using alternative techniques.

However, for larger areas, remote sensing proved to be much more effective in forecasting pests. Remote sensing offers improved spatial and temporal resolution compared to traditional insect monitoring methods, such as sex pheromone traps, light traps and suction traps.(8) The wavelength of electromagnetic radiation (EMR) varies depending on its interaction with the plant surface. Thus, the health and vigour of plants can significantly influence the reflectance patterns of their leave.(9)

Artificial intelligence plays a crucial role in understanding remote sensing data like cropping systems, environmental conditions and physical characteristics associated with plant diseases and insects. It perceives the complex patterns in the data and provides suitable solutions. It is widely used to detect infestations by insects, as well as the presence of these insects themselves. Using a near-infrared (NIR) and hyper-spectral imaging system, researchers differentiated healthy wheat kernels from insect-damaged ones in storage by employing proximal remote sensing and hyper-spectral reflectance profile.(10).

The stress levels and severity caused by leafhopper attacks on cotton plants were assessed by evaluating chlorophyll content and relative water content (RWC) using ground-based hyperspectral remote sensing.(11) On the other hand, an AI model was developed by combining convolutional neural networks (CNN) with long short-term memory (LSTM) models to analyze raw imagery data for assessing insect damage in wheat crops. The proposed model achieved a significant accuracy improvement of 74 % compared to traditional methods and outperformed other deep learning models by 50 % (12)

The “GeoAgriGuard “is an AI-driven remote sensing system for managing insects and diseases(13). It collects data using multispectral and hyperspectral imagery, as well as drone technology. The system employs a combination of AI models.including ResNet, Transformer, DenseNet and AutoEncoders, to process the gathered data. It achieves an impressive accuracy of 97.81 %. The model generates risk maps, which enable farmers to implement timely management practices.

Prediction Models and Forecasting Using IoT-AI Technology: With further developments in hardware and communication technologies, insect monitoring is advancing to the next level. Insect population can be predicted promptly at different localities in a major region using meteorological factors like temperature, relative humidity, rainfall, etc., In this context, we can predict when the incidence of any insect pest will occur, providing users with sufficient time to respond and reduce the insect pest population.(14)

In general, pest data were collected by counting the number of insects caught on light traps, sticky traps, etc., However, recent advancements attempt to automatically count insects on traps by installing cameras and sensors. Similarly, meteorological data are obtained from sensors installed in the field and analyzed using machine learning models to forecast insect populations. By combining historical data and weather correlations, we can achieve accurate and timely prediction for effective pest control (15). A prediction model for Helicoverpa armigera has been developed that correlates weather parameters (temperature, rainfall, sunshine hours and relative humidity) with pheromone trap catches (16). Recent advancements have been made in developing predictive models for monitoring vectors of major diseases. Predictive models have proven effective in monitoring vectors of various diseases, including Anopheles spp., Aedes spp., Culex spp., triatomine bugs, lice, ticks, fleas and black-flies.

Despite the promise, this phase faces challenges such as high initial costs, maintenance requirements, limited connectivity and the need for large annotated datasets to train accurate and regionally adaptable models. Nonetheless, Phase 3 represents the future of pest surveillance in India combining artificial intelligence with automation, mobility and precision farming tools to offer a scalable, field-ready solution for sustainable pest management

Conclusion

The present review study pointed out that recommended improved integrated management of pest and insect along with larvae, application of Artificial Indigence.The integration of automation and AI technologies is poised to revolutionize agricultural practices, enabling autonomous drone systems capable of adaptive, data-driven management tailored to specific crop requirements and environmental conditions. Moreover, advancements in regulatory frameworks and standards will be essential to ensure safe and responsible pest and insect management, addressing concerns related to privacy, crop management, and environmental protection.Collaborative research initiatives, spanning academia, industry, and government sectors, will play a pivotal role in driving interdisciplinary innovation, fostering knowledge exchange, and accelerating the pace of technological advancements in Artificial indigence technology for agriculture. By harnessing the collective expertise and resources of stakeholders, the agricultural sector can harness the full potential with this review.

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