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Role of Artificial Intelligence in Crop Protection

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Abstract

In the era of 21st century, agriculture is facing many challenges now-a-days to feed the world population. The population growth is increasing day by day and it expected to cross 10 billion by 2050. Agriculture farming plays significant role in growth of Indian economy. India stands second in farm production all over the world. After the green revolution, India face production loss with an estimate of US$ 36 billion. The agriculture production decreases mainly because of insect pests, diseases and weeds in important agricultural crops. Hence, there is a need of transition in farming system to adopt advanced and innovative technologies for more and sustainable production. In recent years Artificial intelligence gained popularity in agriculture and provides solutions in several areas like big data analysis, pest and disease forewarning models, mobile applications in IPM, Information and ICT based crop-advisory system, insect detection, pest and disease identification, *etc*. In the proposed paper, AI based applications discussed in detail to provide insights into innovative technologies and pave the way for knowledge dissemination and adoption of AI based technologies for more effective crop production and protection.

Keywords: Agriculture, Artificial Intelligence, Crop protection, Integrated pest management, Insect detection, Mobile application

Introduction

Agriculture is the backbone of Indian economy and India stands second in the world in agriculture production. The progress of Indian economy is directly proportional to the growth of industry in agriculture sector. After green revolution, there is an estimation of farm production loss of US$ 36 billion in India (Dhaliwal *et al.*, 2015). The agricultural production is less because of insect pests, crop diseases and weeds occurring in important agricultural crops (Kavi Kumar and Parikh, 1998). Hence, there is a need of transition in farming system to adopt advanced and innovative technologies for more and sustainable production. Traditional farming methods are becoming outdated, need for advanced innovative technologies to increase the crop production. In recent years artificial intelligence (AI) gained popularity in agriculture and provides solutions in several areas like Information and Communication Technology (ICT), pest and disease forewarning models, mobile applications in integrated pest management (IPM), AI driven crop-advisory system, insect detection, pest and disease identification, *etc*. In the proposed paper, AI based applications in agriculture is discussed in detail to provide insights into innovative technologies and pave the way for knowledge dissemination and adoption of AI based technologies specifically in agriculture for more effective crop protection and production.

AI Applications in Crop Protection

AI based Crop Monitoring System

Crop protection is the general practice for protecting crops from pests, diseases, weeds which cause damage to the crops and affects the yield. Integrated Pest Management is an important area in crop protection for streamlining the management practices and adopting innovative technologies and knowledge dissemination to the farming community is very much essential.

Artificial intelligence (AI) is reconstruction of human intelligence by use of software coded heuristics. Internets of Things (IoT) is a device with inbuilt sensors for recognizing light, temperature, rainfall and humidity and automatically

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capturing the weather information and send it to the computer server/ Cloud; hence IoT helps to transmit the real-time data to the computer server. The combination of AI and IoT call it as the Artificial Intelligence of Things (AIoT) infrastructure facilitate efficient solutions in crop monitoring system such as plant growth, nutrition deficiency, forewarning of pest and disease occurrences, effect of environmental factors to address the issues in crop health and monitoring system. The farmers can take up the corrective measures in advance and the crop loss can be avoided. The block diagram given in figure 1 represents the integration of E-crop which is IoT facility and AI based crop pest forewarning system and crop advisory system *via* mobile phones, social media, *etc*.

There are several IoT sensors to find out the soil moisture, leaf moisture in the plant and to record weather parameters like rainfall, temperature, relative humidity, solar radiation, wind speed and wind direction. The geographical data is

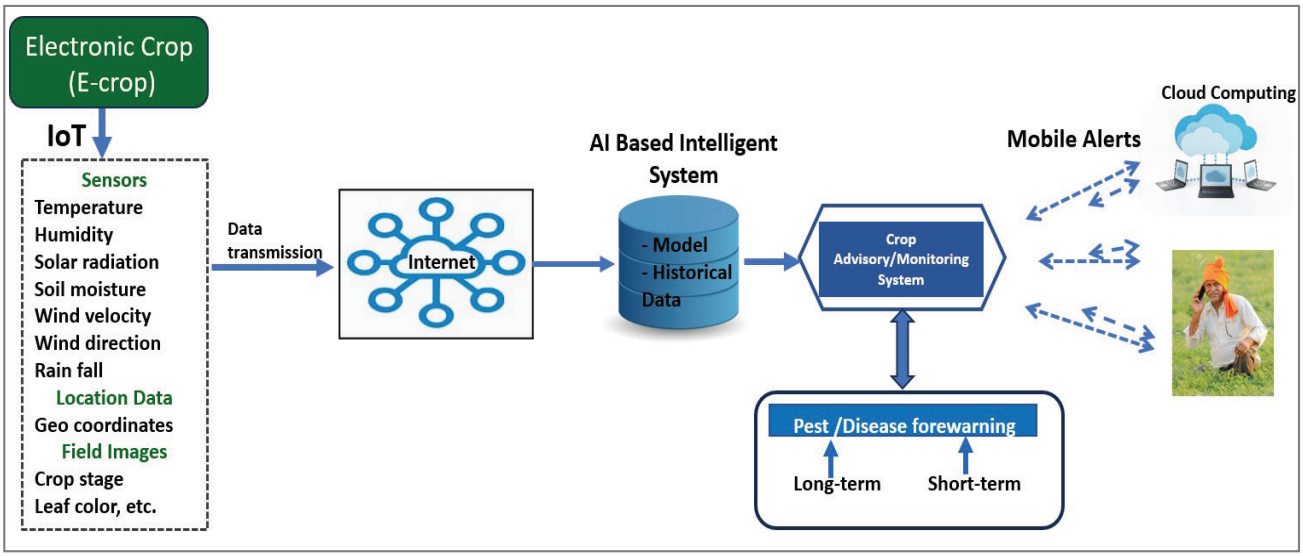

Figure 1: Integration of IoT and AI in Crop Monitoring System

playing a role for finding the exact location on the earth and linking with geo-coordinates always useful to know about the exact place and for corrective measures. The IoT sensors sends the captured data of weather parameters and other environmental data, field images *via* internet to the AI based intelligent system for crop monitoring and pest and disease forewarning. The AI based intelligent system contains crop models and the historical data. Based on the data captured *via* IoT system and the knowledge base stored in the intelligent system, AIoT crop monitoring system advise the farmers and stake holders for any of the major problem occurs in the crop with suggestions to take up to protect the crop. Now-a-days IoT sensors are being used for capturing the field data by use of drones as well.

An advanced electronic device called Electronic Crop (E-Crop) developed by ICAR-CTCRI to simulate the crop growth by integrating the real-time climate and soil data collected from the sweet potato field and named as SPOTCOMS model. This device works with solar power and it is weather proof installed in the field (Mithra and Somasundaram, 2008). This device can be a model device to incorporate the E-crop and AI based model in other agricultural crops.

AI in Insect Pest Detection

Insects are most abundant life forms on earth and consist of more than 1 million species among the vertebrates, invertebrates, plants and others (IUCN, 2011). With reference to the past time and events, the pest and disease recognition was supported by Krishi Vigyan Kendras (KVK's), Non-Governmental Organisations (NGO's), Plant Health Clinics (PHCs) and extension workers. But, presently, similar efforts have been supported through Information and communication technology (ICT) by providing alerts and advisory measures for pest infestation online and through mobile phone services. Awareness about the pest and beneficial insects call it as natural enemies are important to avoid the usage of pesticides and to conserve the natural enemies in the crop ecosystem.

An automated tool for identification of insects based on taxonomical keys with professional-level accuracy was developed up to family level identification of flies and beetles (Valan *et al.*, 2019). Two species of thrips identified by using TRAJAN neural network simulator and statistical analysis based on morphological characters and morphometric data (Fedor *et al.*, 2014). Neural network has been used for insect classification as harmful and non-harmful in cotton ecosystem (Gassoumi *et al.*, 2000). Android based application for digital insect identification was carried out by using Inception-V3 CNN algorithm and this application was able to classify the different type of insect as, *viz.*, bee, beetle, butterfly, cicada, cockroach, dragonfly, fly, grasshopper, mantis, wasp with input of 200 images (Guiam and Bawagan III, 2017). The characteristic feature of colour and shape of the insects were used for classification of insect types (Hassan *et al.*, 2014). An automated insect identification tool was developed by incorporating pattern recognition technique and able to classify the insects up-to order level (Wang *et al.*, 2012). Insect identification system was developed to detect the

species of butterfly, *e.g.*, *Bicyclus anynana*, by using machine learning algorithms, based on the features of eyespots like circularity and symmetry (Silveira and Monteiroc, 2009). A model has been developed for identification of leaf pest as well as disease by using image processing techniques (Ngugi *et al.*, 2020).

TNAU developed 'Uzhavan' app for disease/ pest detection for paddy by using Artificial intelligence techniques (Anonymous, 2023). Digital image processing techniques are used for insect shape detection for sugarcane pests by taking the images from reliable web pages (Thenmozhi and Reddy, 2017). Insects were identified for several species of Lepidoptera, Coleoptera and Orthoptera with accuracy of 95% to 97% by applying deep convolutional neural networks and publically available insect datasets have been used (Thenmozhi and Reddy, 2019).

The AI technique, Convolutional Neural Network (CNN), VGG19 algorithm proposed for classification of insects up-to 24 species by using the Xie's data set and the images gathered from the crop farmlands and internet (Xia *et al.*, 2018). But this model has target detection error. AI technique has been used for real-time insect monitoring and its management (Fedor *et al.*, 2009). Several efforts have been carried out in this research and still further accurate and robust models are required especially for agriculturally important insects.

Agricultural Robots

Use of machines or robots to perform the difficult or routine tasks generally carried out by human beings. Robots are popularly used in industries to perform certain tasks where the tasks were too difficult to perform or hazardous to humans. Agricultural robots are being used for weeding out, harvesting, pruning, seeding and spraying pesticides. Drones are being used to capture the aerial images of agricultural field for quick crop health assessment. Agriculture Robot has been developed for detecting the insects belongs to the Pyralidae family with same as expert's intelligence. This robot has intelligence to detect the Pyralidae insects and captured the images in the field. This agricultural robot comprises of the hardware components like personal computer and embedded electronic circuit boards designed with computer programs and camera module with software components as Windows operating system, Embedded Linux operating system, Python and OpenCV (Hu *et al.*, 2019). This robot could able to execute the motion as per the instruction, capture the images from the field and identify the insects of Pyralidae family. In this proposal the authors used the triangle shape to feature to identify the Pyralidae insects with accuracy of 94.3% in maize crop (Figure 2). More research work is essential to detect other group of insects in many of the agricultural crops.

Pest monitoring by using wireless sensor networks has been implemented to study the insect behaviour on five crops *viz.*, Potatoes, Wheat, Rice, Corn, Tomato and its associated insect pests (Singh *et al.*, 2022). Pests and diseases are a big menace to food security, timely and correct finding and remedy is essential to avoid the loss in crop production. The Plant village dataset has been used extensively by applying deep learning Convolutional Neural Network (CNN) models for disease identification and this Plant village dataset contains 54,306 coloured images of leaves with 26 disease symptoms of 14 crops (Mohanty *et al.*, 2016). Transfer learning approach has been used for identification of plant diseases on 12 crops (Barbedo, 2019). Artificial intelligence technique, deep learning method Efficient Net model was used for wheat disease identification with 99% accuracy (Nigam *et al.*, 2023). Artificial intelligence technique convolutional neural network (CNN) and transfer learning algorithms have been used for banana diseases and pest detection with 90% accuracy (Selvaraj *et al.*, 2019). Further, research work is required for disease identification on important agricultural crops by applying machine learning techniques in remote sensing and aerial images.

AI based Mobile Applications

Mobile Application is an Information Communication Technology (ICT) application to run on mobile phones, tablets and also in desktop computers *via* internet. Mobile application plays a major role in agriculture extension services to disseminate the knowledge and information in an easy and efficient manner to the farmers and other stake holders. Mobile application makes the user to feel an interactive way because of its ability to convey the information in multimedia mode. Large number of mobile applications developed in the field of agriculture on different aspects to give advisory to the farmers. Artificial Intelligence (AI) techniques are required to disseminate the knowledge about several themes in crop protection for sustainable agriculture. The mobile applications developed with AI technology are specified in table 1.

Currently, several mobile applications are available, which furnish most recent agricultural information regarding agricultural marketing, farming machinery, crop pest and disease advisory setup, real-time weather data, *etc*. The mobile app Kisan Suvidha furnish important information, *viz*., weather data of current day and the coming 5 days, market rate of the agricultural commodities, crop advisories, crop protection, *etc*. quickly to the farmers with the state-of-art, click of a button. The damage of insect pests affects the agricultural production. Increasing the usage of pesticides in pest management is the concern now to protect the biosphere and human well being. Knowledge dissemination about the biological control of crop pests is necessary among the farming community. Several mobile apps are available for various crops like pomegranate, banana, papaya, fodder crops, arecanut, chilli, tomato, cotton, rice, castor, *etc*. in Google play store as well as in ICAR institute websites. But, video clips and texts on biological control measures are missing which is required for explanation and recommendations in pest management. Hence, user friendly mobile apps for biological control of crop pests are required in regional and local languages so that the transfer of technologies in this aspect will speed up to adopt the technologies. There are several mobile apps

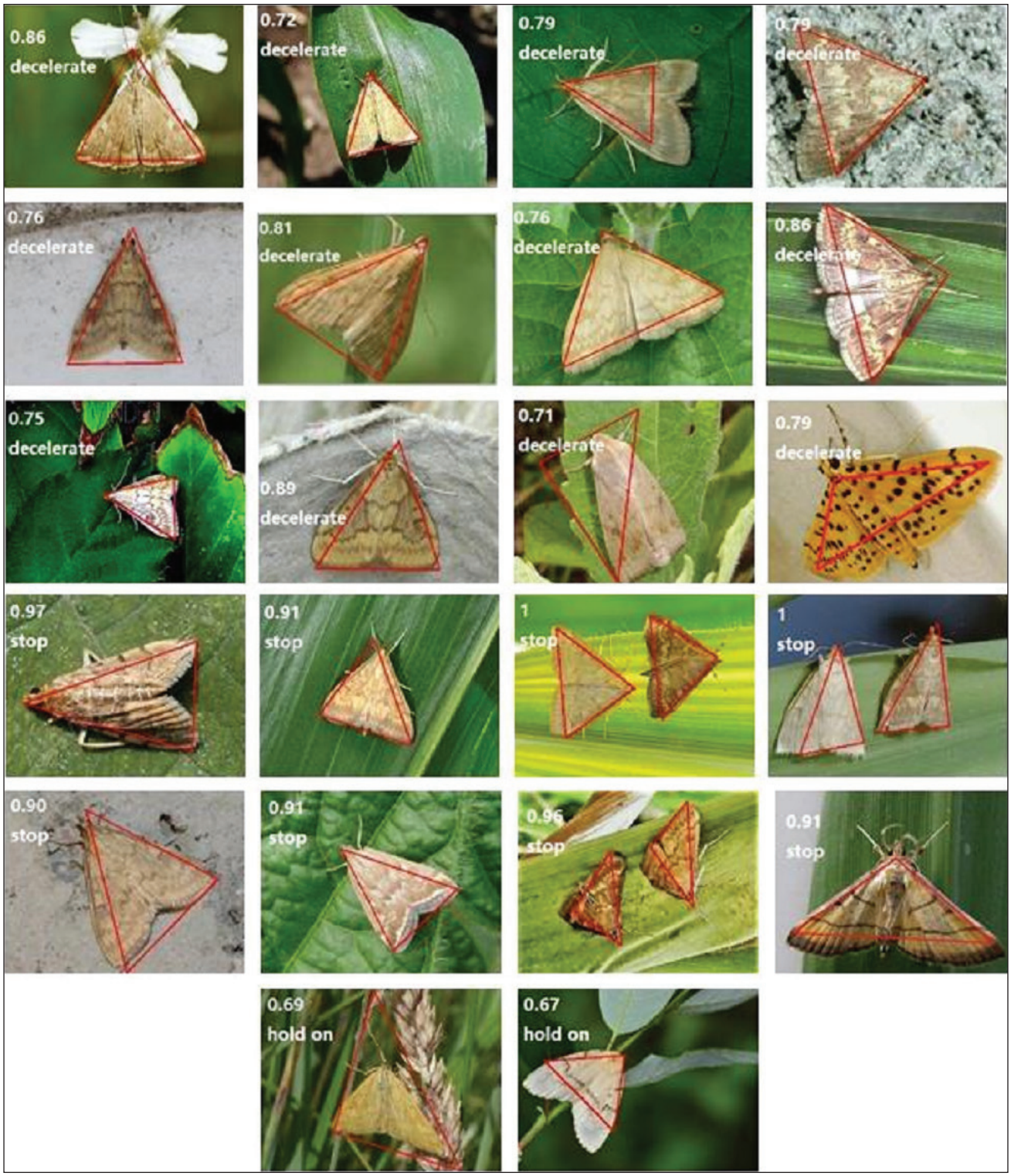

Figure 2: Using of triangle shape to identify the Pyralidae insects in maize crop (Hu *et al*., 2019)

developed in IPM with special focus on biological control methods, *viz*., Shatpada-BPM-2, BIPM on Rice, BIPM on Sugarcane, BIPM on Coconut, BIPM on FAW-Hindi, BIPM on FAW-Telugu, BIPM on FAW-Marathi, BIPM on FAW-Tamil, BIPM on FAW-Kannada, BIPM on FAW-NE(IND) and BIPM on Tomato pinworm by ICAR-NBAIR, Bengaluru, India and these mobile apps are freely available in Google play store. Shatpada-BPM-2 helps to know about the pest management on rice, sugarcane and coconut crops by using biological control methods. BIPM on Rice, BIPM on Sugarcane, BIPM on Coconut gives holistic approach for pest and disease management on rice, sugarcane and coconut crops with special focus on biological control methods. BIPM on Faw has been developed to disseminate the knowledge about the invasive pest fall armyworm (FAW) in maize crop and its management by using biological control, pheromone and chemical methods. This mobile app is available in multiple Indian languages, *viz*., Hindi, Telugu, Marathi,

Table 1: List of AI based mobile applications

Sl. No.	Name of the Mobile application	Usages	Weblink
1.	Plantix	This mobile app is being used for fruit crops, vegetable crops and field crops as diagnostic tool for pest and diseases and also to identify nutrient deficiency.	https://plantix.net
2.	PlantNet	This mobile app helps to identify plant species based on the photographs by using image recognition software.	https://identify.plantnet.org/
4.	iNaturalist	iNaturalist helps to recognize the plants and animals based on the images.	https://inaturalist.org/
5.	ripeSense	This acts as intelligent sensor gives indication to know about the ripeness of fruit based on the colour changes in the fruits.	https://product.statnano.com/product/6730/ripesense
6.	CropIN	This mobile app is an intelligent system that delivers real-time farming solutions to the whole agricultural sector.	https://cropin.com/
7.	Agribotix	Agribotix provides the real-time agricultural intelligence services.	https://agribotix.com/
8.	eNirog	This mobile app is designed with innovative ideas to detect the pest and diseases on important crops growing in Bihar state, India.	https://play.google.com/ https://play.google.com/store/apps/details?id=com.enirog.plantdiseaseclassifierV2&hl=en_US

Tamil, Kannada and North-Eastern Indian languages Bengali, Assamese, Khasi, Manipuri, Nagamese and Nepali. Farmers, students and extension workers can download this mobile app from Google play store. These mobile apps are act as ICT tool to disseminate the knowledge about integrated pest management on important crops like sugarcane, rice, coconut, maize and tomato. The mobile app, "BIPM on Tomato pinworm *Phthorimaea absoluta*," has been constructed by using Artificial Intelligence technique (Pratheepa *et al.*, 2022). This mobile application developed in a web-interface platform where the user can view the application in Android mobile phone and also in desktop computer *via* website address. This mobile application is useful for knowledge dissemination about the pest details and also to identify the tomato pests in the field by capturing the field images and uploading in this mobile app by using the feature "DIAGNOSTICS". These mobile applications are to be reached to the farming community for technology adoption and State agricultural departments involve KVKs for training and knowledge dissemination of these applications.

Decision Support System with AI Technology

A decision support system (DSS) is a software model, which built a framework by integrating database management systems, data analytical tools in order to facilitate and support in decision-making process. Farmers face several problems like yield loses due to pest and diseases, weed, soil erosion, increasing chemical pesticides cost, declining market prices, *etc*. An advanced AI-driven DSS with accurate agricultural practices can help the farmers, stake holders and policy makers to take correct decision and appropriate measures in integrated pest management (IPM). Recently, Govt. of India has taken an initiative to develop Krishi-Decision Support System (Krishi-DSS) by utilizing geospatial data and database technologies to guide the stake holders and policy makers to take appropriate decision in agriculture sector. There are several DSS available in the field of agriculture and few of them are mentioned here.

The DSS, call it as 'CROP-9-DSS' has been developed crop pest and disease detection and crop advisory including fertilizer recommendation and water management for the prime crops in Kerala, *viz*., Coconut, Rice, Cashew, Pepper, Banana and the vegetable crops like Amaranthus, Bhindi, Brinjal and Cucurbits and act as a handy tool to the agriculture extension workers, officers in decision making process to suggest appropriate recommendations to the farmers (Ganesan, 2007).

DSS combined with Geo-graphical Information System (GIS) contribute to know about the spatial and temporal variations in natural resources directly linked with agriculture. DSS with spatial data of crop acreage in India and crop productivity on various crops, *viz*., Sorghum, Pearl millet, Pigeonpea and Chickpea was developed and this GIS based DSS helps the policy makers in decision making process like farm items distribution, *etc*. (Sehgal *et al.*, 1992).

Robust DSS are needed in agriculture especially for pest and disease forewarning and recommending system to take up the accurate control measures to increase the crop productivity.

Conclusion

Educating and equipping with information and communication technology (ICT) to the farming community in India is a big task and the Government of India and State governments took initiative for IT infrastructure in the past decade. But

still there is a gap in accurate AI based technologies in crop protection, technology implementation, digital literacy, availability of advisory services, mindset of the farmers for technology adoption, *etc*. Therefore, the attitude and mindset of the farmers need to be changed and Krishi Vigyan Kendras, State agricultural departments should take more initiative to provide training and awareness to the farmers. AI costs high but this will be one-time investment and the same system can be upgraded with new findings. AI has huge potential and the applications will be a standardized tool in near future in crop protection and improvise the crop production for food security.

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