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Role of Modern Tools and Information Technology *vis-à-vis* Artificial Intelligence in Rice Pest and Disease Management : An Overview

Manas K. Bag[1], Raghu S.[1], Prabhu Karthikeyan S.R.[1], Jeevan B[1]., Partha S. Roy[2]*

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ABSTRACT

Agriculture sector faces lot of challenges in order to maximize its yield and quality produce. All these challenges include improper soil treatment, disease and pest infestation, big data requirements, low output, and knowledge gap between farmers and technology. Among these pest and disease problems are also the major problems. Present trends of crop management are application of modern molecular tools and incorporations of IT and AI which are interlinked and dependent each other. This article presents an overview of the applications of modern tools in pest and disease management.

Key words : Rice, Pest, Disease, Genome editing, Hyperspectral, Nanotechnology, IoTs

Introduction :

Plant, pathogen and insects, are natural creatures and all should co-exist in the earth but certain insects and pathogens occur in the entire growth period of the crop that causes a huge reduction in crop production. This reduction is not only due to yield losses but also includes significant losses in the quality of the produce. Rice is one such crop and is one of the most important pillars of food security in India. To meet the future demand of food, earning substantial amount of foreign currency through export, and also to sustain present self-sufficiency, rice productivity has to increase from present 2.56 to 3.25 t ha^{-1} by 2050. Globally crop plants losses 20% to 40% yield per year due to pests and diseases (Savary *et al.*, 2019). On an average 37% loss of rice yield is due to pest problems (Sparks *et al.*, 2012). As per FAO estimates each year 40% of crop yields are reduced globally due to damages caused by plant pest and diseases. Besides quantitative loss qualitative loss is also cause of concern now-a-days, like false smut of rice significantly reduces germination ability, filled grain number, seedling vigor index (Bag *et al.*, 2016) and affects the grain quality such as amylase, total protein, antioxidant, total phenol content and other important cooking qualities (Bag *et al.*, 2017; Bag *et al.*, 2021). As per the information available from All India Coordinated research Project on Rice

[1]Crop Protection Division, ICAR- National Rice Research Institute, Cuttack, Odisha- 753006;
[2]O/O The Joint Director of Agriculture (P) (Admn), Medinipur Sadar Subdivision, Abash,
*Email : manas.bag@gmail.com

(1965 to 2017), at present in India number of major rice insect pests and diseases are 20 and 10 respectively. At present rice crop is facing some major and emerging pests and diseases like, like brown spot (*Bipolaris oryzae*), blast (*Magnaporthe oryzae*), bacterial blight (*Xantomonas oryzar pv oryzae*), sheath blight (*Rhizoctonia solani*), bakanae (*Fusarium moniliformae*), sheath rot (*Sarocladium oryzae*) and false smut (*Ustilaginoidea virens*), brown plant hopper (*Nilaparvata lugens*), yellow stem borer (*Scirpophaga incertulas*), rice leaf folder, (*Cnaphalocrocis medinalis*), apart from this there are many minor pests which are acquiring the major pest status under changing climatic scenario like gall midge, whorl maggot and white backed plant hopper. Moreover, global climate change also influences the behavioural changes of insect and pathogens that force the researchers to be more dynamic in their researches in finding out and updating the data bases with more and more resistant donors and application of latest technologies like genome editing for developing resistant/tolerant varieties. Crop pest and disease management is really a complex subject. Recent scientific advancements havelot of potential applications, i) development of resistant or tolerant varieties for the endemic areas, ii) development of cost effective, time-saving and robust techniques for pest and disease diagnosis at the early and even non-symptomatic stages, iii) timely application of eco-friendly green pesticides or Nano formulation of botanicals /chemicals to intervene spread of disease and pests in smoother way, iv) modern techniques of pesticide spraying through drone technologies, in the area where manual operations are not possible or non-competitive. Moreover, recent advancements in the internet of things (IoT), that integrates both information technology (IT) and artificial intelligence (AI), also have the potential impact and can bring radical changes in the areas of pest and disease management.

Advances in resistant variety development :

Host Plant Resistance (HPR) study is very important for developing resistant varietyand this is also the backbone of integrated pest management (IPM) in order to increase the production and productivity to meet ever growing human population (Godfray *et al.*, 2010). Resistant variety can provide an effective and economical way for management of insect pest and diseases particularly in endemic areas. Understanding the genetic diversity of insect pest and pathogen population require continued effort in introducing new resistance gene/QTL sources against a virulent biotype or biovar/pathotypes. Wild species possess important sources of HPR genes/QTLs which have considerable amount of resistance. Few recent studies shown that, some wild relatives have genetic components that provides genetic gains in terms of improved agronomic performance along with pest resistance. After so many years of screening of huge number of landraces, resistant donors are not found for sheath blight and brown spot diseases. Several QTLs are identified for the respective rice diseases which are introgressed through gene pyramiding to develop resistant varieties. In general, 6-8 generations are required to transfer the pest/pathogen resistant traits from source to high-yielding cultivars in conventional breeding. But molecular marker technology had reduced the time and space. Gene pyramiding is a powerful tool for integrating multiple disease-resistant genes in a serious manner by repetitive backcrossing and selection. The use of multiple resistance genes into an elite variety represents an ideal means for achieving the sustained control of insect and pathogen in rice. 38 BPH resistant genes have been explored on various rice chromosomes in cultivated and wild rice species (Anant *et al.*, 2021). Recently, three QTLs like qShB-1.1, qShB-1.2 and qShB-1.3 have been identified in a cross between CR-1014 and Swarna Sub-1 in F2 and F2:3 generations (Bal *et al.*, 2020).

RNAi/ gene silencing :

Gene silencing is basically a homology-based process which is triggered using double stranded RNA (dsRNA), causes gene silencing in a sequence-specific manner leading to the suppression of gene expression. Gene silencing can be executed at transcriptional gene silencing (TGS) and post transcriptional gene silencing (PTGS) levels. The TGS involves targeting genes at DNA level. The PTGS techniques rely upon the breakdown of mRNA by various technologies, including antisense RNA, ribozymes, DNAzymes, microRNAs, and RNA interference (RNAi). Among all these techniques, RNAi is the most efficient tool for targeted gene silencing. The specific RNAs are targeted and degraded in RNAi mechanism. The long dsRNA is cleaved into small (21-25 nucleotides) fragments basically by a complex called Dicer, (RNase II family) and these small RNAs produced are then incorporated into a complex 'RNA-induced silencing complex' (RISC). Then the RISC is targeted to degrade single-stranded RNA (ssRNA) in a sequence-specific manner; specificity being provided by the sequence of the small RNAs. RNAi is now routinely utilized for genetic studies and agriculture, particularly for managing insect species, plant pathogens and nematodes in different crops.

In rice plants, gene silencing of OsDCL1 gene exhibited increased resistance to the rice blast pathogen, Magnaporthe oryzae, in a non-race specific manner. RNA-dependent RNA polymerase (RdRp) genes were considered to have the vital roles in gene silencing and conferring resistance to the plant pathogens. Inactivation of rice RdRp6 gene showed increased susceptibility to Rice necrosis mosaic virus, Xanthomonas oryzaepv. oryzae or Magnaporthe oryzae. Tiwari *et al.* (2017) first time demonstrated the host delivered RNA interference (HD-RNAi) technology to silence the Rhizoctonia solani pathogenicity MAP kinase 1 (PMK1) homologues genes RPMK1-1 and RPMK1-2 using a hybrid RNAi construct. The results revealed that transgenic rice lines were showed delayed sheath blight symptoms and reduced disease as compared to non-transformed controls. In the last two decades, RNAi has been emerged as an important molecular tool to silence key gene transcripts in many of insects comprising orders such as Coleoptera, Hemiptera, Diptera, Hymenoptera, and Lepidoptera. For example, ecdysone receptor (EcR) is a worthy target for RNAi approach to control brown planthopper (BPH) in rice. Silencing NlFer1 or NlFer2 genes led to slow growth and 100% mortality (Shen *et al.*, 2021).

Genome editing by CRISPR/Cas9 approach :

As a new breeding technology (NBT), genome editing (GE) became rapidly popular among the researchers. In contrast to genetically modified (GM) crops, GE derived varieties generally will not possess any foreign DNA and thus will not subject to additional regulation (Menz *et al.*, 2020). In GE many programmable nucleases are used like Mega nucleases (MNs), Zinc finger nucleases (ZFNs), Transcription activator-like effector nucleases (TALENs) and, Clustered regularly interspaced short palindromic repeats (CRISPR)-associated nucleases (Cas) to target DNA sequence for introducing targeted genome modification (Chandrasegaran and Carroll, 2016).Among this, Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR)/Cas9 (CRISPR-associated protein 9) is becoming highly popular because of its speed, precision and effectiveness. CRISPR-Cas tools can be employed to target plant pathogens to identify virulence genes and delineate or validate the function of effector encoding genetic regions. CRISPR-Cas9 mediated genome engineering was successfully achieved in a wide range of plant pathogenic fungi.Moreover, CRISPR/Cas9 is more robust in terms of complete gene knockdown in comparison to RNAi which induces partial gene silencing and greater specificity.

In rice, the use of CRISPR/Cas9 tool was observed for knocking out of cytochrome P450 gene, CYP71A1 which encodes tryptamine 5-hydroxylase resulted in elevated salicylic acid (SA) levels and reduced serotonin levels in rice plants thus conferring enhanced resistance against brown planthopper the most notorious pest of rice. They used the CRISPR/Cas9 tool and tested the efficiency of knock out and knock in of E-cadherin gene, EGFP and found that E-cadherin gene brings about defects in dorsal closure, which is consistent with RNAi-induced phenotypes. Homology-directed knock-in of marker transgenes was observed in nearly 14% of injected individuals and in the next generation it was observed in 6% of the injected individuals.

Liu *et al.* (2012) demonstrated that RNAi silencing of ethylene responsive factors (OsERF922) increased the rice blast resistance. Thus Wang *et al.* (2016) used CRISPR/Cas9 to knockdown gene OsERF922 in rice plants. *Xanthomonas oryzae pv. oryzae* pathogen causing bacterial blight of rice, translocates transcription activator-like effector (TALE) proteins into host cells via type III secretion system and induces the expression of susceptibility factor genes (S genes) in plants. The susceptibility gene OsSWEET13 was induced by *Xoo* effector protein (PthXo2) and results in bacterial blight disease. The CRISPR/ Cas9 based mutation of OsSWEET13 gene resulted in increased resistance to *Xoo* infection. Similarly, the mutation in the SWEET11, SWEET13 and SWEET14 was resulted a broad-spectrum resistance to BLB pathogen.

A rice PP2A-1 gene, found to be induced in response to *Rhizoctonia solani* infection, was mutated by CRISPR-Cas for the functional validation (Lin *et al.*, 2021). The pp2a-1 knock-out mutant showed susceptibility to sheath blight disease, suggesting a defence role of the PP2A-1 gene. Numerous genes documented to be induced in earlier transcriptomics, proteomics, and metabolomics studies could be targeted by CRISPR-Cas for investigating the extent of their contributions to the resistance or susceptibility of rice to *R. solani*.

Advances in diagnostics of rice pest and diseases :

Diagnosis of pest, particularly diseases at right time preferablyat the early stage of crop growth or the initial stage of infection of pathogen isvery helpful to check spread and facilitate effective managementpractices. On-time identification of disease and its distribution over the affected region couldprovide useful information that help in minimizing the crop losses and sustaining quality of the produce. Lots of advances were done in the domain of pest and disease diagnosis. Different techniques areavailable, but most of them have limited use, mostly laboratory based and costly like polymerase chain reaction (PCR), immunofluorescence (IF), fluorescence in-situ hybridization (FISH), enzyme-linked immunosorbent assay (ELISA), loop mediated isothermal amplification (LAMP) etc. There are some other methods that also have good potential and might be the future of pest disease diagnosislike Flow cytometry (FCM), Recombinase Polymerase Amplification (RPA), Thermography (TG), Fluorescence imaging (FI) and Hyperspectral techniques (HT) and lastly, sensor-based detection methods. Out of these, works on diagnosis of rice diseases through hyperspectral has gain commendable progress.

LAMP :

Identification of causal organisms based on visual symptom of the diseases are gradually reducing its importance because similar type of symptoms produce by different pathogens makes confusion in decision making. In this era of molecular based detection method, LAMP as say givesaccurate and efficient diagnosis. Amplification of very small amount of targeted DNA sequence with highly efficient polymerase enzyme, in a static temperature (usually 63-67ÚC) and loop structure formation of take place when the LAMP primers amplify their target DNA sequences.

This method does require neither full-fledged laboratory nor advanced analytical knowledge. This technique has been used in detection of plant pathogenic bacteria with greater success because of itsnature of isothermal reaction and protocol can be followed in the field using a simple water bath and portable kits. Less time requirement of this technique is its advantage. Now primers have been developed for rice leaf blight (*Xanthomonas oryzae* pv. *oryzea*) and leaf streak (*Xanthomonas oryzae pv. oryzicola*) for LAMP assay, is so specific that even it can detect the pathovar along with distinguish between African and Asian lineage of pathogen (Lang *et al.*, 2014).Recently Banerjee et. al. (2021) developed LAMP technique for detection of pathogen (*Ustilaginoidea virens*) causing false smut disease of rice. Ash *et al.* (2017) developed LAMP technique to detect *Pseudomonas fuscovaginae* that cause sheath brownrot of rice.

Recombinase Polymerase Amplification (RPA) :

Substantial works have been completed for detection of many viral diseases of plant through RPA but for detection of rice diseases is not significant. Recently, Banerjee, *et al.* (2023) standardised the protocolof RPA to detect *U. virens* directly from mycelial crude extract. The sensitivity of RPA was compared with PCR, nested PCR and LAMP assays andonly RPA succeed to detect *U. virens* from crude extract. The specificity of the RPA primers wasevaluated using DNA from other rice pathogens, as well as, by sequencing the RPA amplicons. Further, this assay was validated on 32 *U. virens* isolates collected from different locations of eastern and north-eastern India and also through different symptomatic and non-symptomatic FS samples.

Hyperspectral technique :

In hyperspectral technique, image covers more bands instead of conventional three bands of coloured light and high consistency of colour reflectance is used over a large range of light spectrum that is beyond human vision. Thus, potential minor changes in a plant due to infection of pathogens can be identified. This technique is applied in the study of number of rice diseases.

Rice reflectance measured for determining the spectral region most sensitive to panicle blast infection is 475-670 nm. After the yellow ripe growth stage near infrared light found most suitable (Kobayashi *et al.*, 2001). Hyperspectral reflectance principle used for the determination of different fungal infection level on the rice panicles. Different infection stage of rice panicles which were evaluated was no infection, light and moderate infection due to glume blast, severe infection of panicles due to false smut disease under the hyperspectral range of 350-2500 nm in the portable spectroradiometer.Hyperspectral sensors (ASD field spectroradiometer) were also available for identifying rice brown spot disease (Liu *et al.,* 2008). Application of HT is used for the early detection bacterial blight disease of rice with inclusion of different vegetation indices i.e., NDVI (Normalized difference vegetation index), SR (Simple Ratio), red edge, MCRI (modified chlorophyll absorption ratio index), NPCI (Normalized Pigments Chlorophyll Ratio Index), TCARI (transformed chlorophyll absorption ratio index), OSAVI (optimized soil-adjusted vegetation index) observed (Singh *et al.*, 2010). The step-wise discriminate analysis (SDA) in hyperspectral reflectance coupled with satellite data obtained by LISS (Linear Imaging Self-Scanner) revealed only four band i.e., 760, 990, 680, 540 nm and geospatial maps could analyse for bacterial blight of rice (Das *et al.*, 2015). In another study by Singh *et al.*, 2012 explained the hyperspectral reflectance data, collected for rice crops at different Bacterial Blight disease infestation levels i.e., 0, 30, 50, 60, and 80% by hand-held spectroradiometer over the spectral range of 325–1075 nm. The reflectance curve was partitioned into five regions, viz. 400–500 nm, 520–590 nm, 620–680 nm, 770–860 nm and 920–1050 nm. The significant differences in healthy and diseased rice plants were noticed at 770–860 nm and 920–1050 nm. There was a good correlation between disease intensity and spectral reflectance ranged and it proved that, hyper spectral data is highly useful for bacterial blight of rice disease detection and disease intensity estimation.

Portable sensors based detection :

Another growing area of research in diagnosis field but not significant progress is observed in rice pest and pathogen detection through portable sensors. Different types of sensors are developed and available for use in environment monitoring and medicinal diagnosis. The principle for detection through portable sensors is based on electrical, chemical, optical, magnetic or vibration signals. The sensitivity of sensors can be enhanced by the use of bio-recognition elements. There are some biosensors platforms are available on nanomaterials, antibody, DNA/RNA and bacteriophage.In the nanomaterials-based biosensors, metal and metal oxide nanoparticles are used. These nanoparticles work with other foreign biological materials such as antibody of pathogen which can be easily detectable by portable sensors. Generally, in metals, gold-based nanoparticles are used because of its high sensitivity, specificity, photothermal (i.e. transfer light in to thermal energy), high electric conductivity, electroactivity and single probe sensors. In addition,nanochips are made in microarrays which contain fluorescent oligo probes and helpful in detecting single nucleotide change and which make these sensors more reliable for detection.In the portable sensors quantum dots also used which helps in disease detection. Quantum dots have their advantages as unique optical properties, with fluorescent resonance energy transfer (FRET). Some affinity biosensors are also now applied which work on the principle of biorecognition elements. Antibody based biosensors allow rapid and sensitive detection of wide range of pathogens such as seed, soil to air borne diseases. Antibody based biosensors worked on the principle of immunogens lies in the coupling of specific antibody with a transducer which converts the binding event to a signal that can be analysed. Other biosensors which were developed on the basis of DNA/RNA affinity. These biosensors analyse the DNA/RNA probe which attached to the membrane of pathogens DNA/RNA.

Advances in research of nanotechnology application for rice pest and disease management :

Nanotechnology is another emerging field and has the potential to address some of the important applications in agriculture and pest management is one such highly influenced fields. Nanotechnology provides excellent solutions for an increasing number of environmental challenges like development of nanosensors that has extensive prospects for the observation of environmental stress and enhancing the combating potentials of plants against diseases. But major works advanced in the application of this technology in modification of pesticide formulations vis-à-vis nanopesticides.The production of plant- and microorganism- derived nano-particles (NPs), has emerged as an efficient biological source of green NPs. For getting green nanotechnology, a number of plant species and microorganisms including bacteria, algae and fungi are being currently used for NP synthesis. Recently Adak et. al. (2021) developed green NPs from rice leaf extracts. The benefits of nano pesticideare reduction of the pesticide quantity per hectare, costs of cultivation, and enhancement of efficacy and specificity like properties of the molecules. Generally, management of the pest and diseases depends mostly on persistent uses of pesticides but their continuous application may arise problems like, resistance development of the pests, environmental pollution and handling hazards that lead to unintended poisoning threats to humans. In recent years, more scope is there for the development of safer eco-friendly pesticides from products of plant origin viz., essential oils (EOs) and botanical extracts. These are another novel alternative to chemical (pesticides) to meet new regulatory norms and consumers demand of safe foods which have significant effects against a large number of stored grain insects because of its non-phytotoxic nature and effective against numerous insect pests and diseases. Basically, EOs are volatile in nature and their secondary metabolites are characterized by strong aroma and having density lower than water (Bakkali *et al.*, 2008). It has been also proved that biologically originated products have useful insecticidal attributes (Arthur, 1996). Now, these EOs are levelled at par with pesticides in terms of efficacy (Isman *et al.*, 2011), because of its properties like selective bioactivity and little or no harmful effects on non-target organisms and environment (Regnault *et al.*, 2012). Hence the present proposal is aimed at identifying natural, safer and eco-friendly option as an alternative to chemical insecticides to manage stored product insect pests. Adak *et al.* (2019) recently developed nan-emulsions of eucalyptus oils that is highly efficacious against major storage grain pest.

Four types of nano-pesticides viz., nano-emulsion, nano-suspension, nano-capsules and nano-particles are available. Nano-emulsion formulations are the emulsion of either water in oil (W/O) or oil in water (O/W) that produces a transparent product having 20-200 nm droplet and does not have the propensity to coalesce. Controlled release of nano-formulation can overcome problems like chemical instability in the presence of high temperature, light, and moisture. Some of the high-energy emulsification methods used to make nano-emulsions are high-pressure homogenization, high-shear blending and ultrasonication (Ghosh *et al.*, 2013). These nanoparticles act like magic bullets having precise, target oriented delivery system and effective penetration of molecules through cuticle and tissues. The main objectives of these formulations are i) deliver precisely on target site and ii) its property of slow releasing pesticides. Thus, nano-formulations are more potent compared to conventional formulations. Thus, nanotechnology can provide efficient and safe alternatives for pests and disease management as well as stored products also.

The convergence of nanotechnology with biotechnology also provides opportunities as new tools of molecular transporter to modify genes and even produce new organisms(Lyons, 2010) (Fig.1). For instance, nanobiotechnologies implicate nanoparticles, nanocapsules, and nanofibres to carry foreign DNA and the chemicals that facilitate to modify the target genes. Contemporary advances in nanomaterials-based specific delivery of CRISPR/Cas9 single guide RNA (sgRNA) has commenced a new era in genetic engineering. For example, cationic arginine gold nanoparticles (ArgNPs) assembled Cas9En (E-tag)-RNP (ribonucleoproteins) delivery of sgRNA provides about 30% effective cytoplasmic/nuclear gene editing efficiency in cultured cell lines, which would greatly facilitate future research into crop development (Mout *et al.*, 2017).

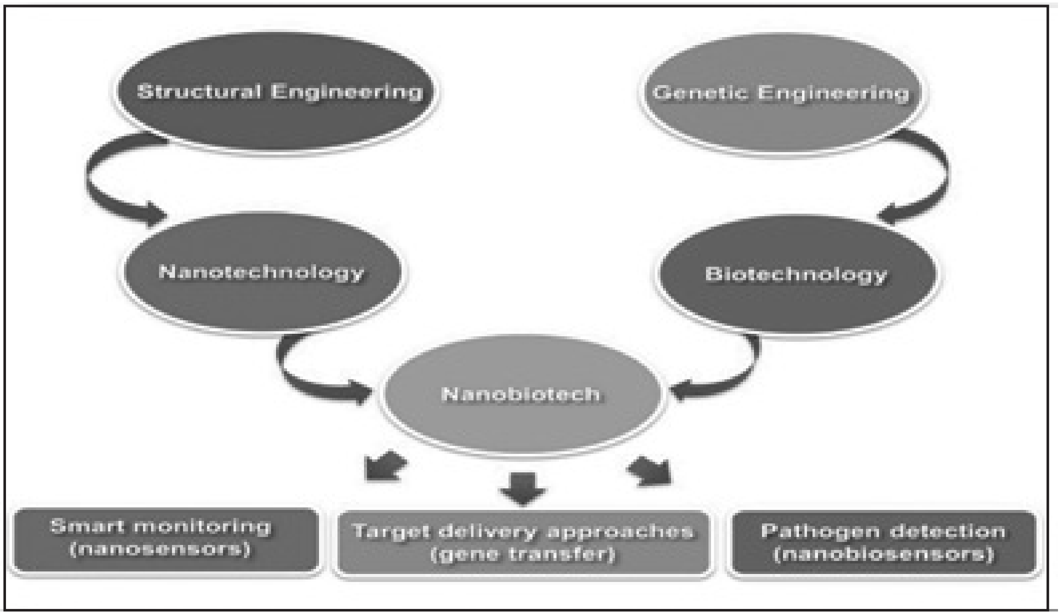

Figure 1. An overview of nanobiotechnology (Source: Sang *et al.*, Molecules 2019, 24, 2558)

Smart technology for pest and disease management :

Agriculture sector is now adapting slowly and steadily the modern technologies and thus the pest and disease management also is on the way of deploying those technologies.

***Drone technology* :**

Drone technology is a phenomenal innovation that have enough potentiality to transform the conventional farm practices followed in Indian agriculture. Spraying pesticide operation in the rice crop is most tedious. Pesticide spraying has to be standardized with mechanization/ advanced equipment like drone in order to meet labour shortage, avoiding pesticide exposure, and to reach into the uncovered field area for smarter way of pest and disease management. There is huge potentiality of drone technology for growth in agricultural fields. With constant improvement of technology, imaging process of the crop also needs improvement so that the farmers are being able to analyse their crops and can make proper decisions for further process by means of analysing the data captured by drone and help them to get accurate crop information.

This technology has the potential to provide a sustainable solution in context of enhancing the productivity as well as efficiency in the agriculture sector. It empowers the farmer to manage some of the specific environment and make pertinent choices to regulate crop health.

Recently Government of India has recommended the usage of drones for spraying operations to control the locust as band application and save the crops as a special case. But for other cases, Unmanned Aerial Vehicle (UAV) spraying is not recommended in India. More recently (16th July, 2021), the Directorate of Plant Protection, Quarantine & Storage, Faridabad has published a draft 'Standard Operating Procedures (SOP)' for use of drone application with pesticides for crop protection. However, there is no crop-specific SOP for rice, hence, there has to be some preparedness in terms of robust and pragmatic science-based research.

Internet of things (IoT) **:**

Basically, the internet of things (IoT) is one of the most advanced technologies that facilitates smart agriculture. IoT generally add sensing, automation and analytics technologies to modern agricultural process. The common applications of IoT in pest and diseases management have direct or indirect role in smart agriculture are: sensor-based systems for crop monitoring with respect to pest disease diagnostic, disease pest forecasting, predictive modelling and planning, smart agricultural vehicles, drones, robotics, data analytics, visualization and management systems. This IoT is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers (UIDs). This technology has the ability to transfer data over a network in absence of human-to-human or human-to-computer interaction. An IoT system consists of web-enabled smart devices that use embedded systems, like processors, sensors and communication hardware, to collect, send and act on data they acquire from their environments. It shares the sensor data which are collected by connecting to another IoT gateway where data is either sent to the cloud to be analysed or analysed locally. Maximum work is done by this system without human intervention, though people can interact with the devices, like setting and give them instructions or access the data. IoT is a comprehensive adoption of new information technology. Combination of IoT technology with modern agriculture gradually bring smart agriculture into people's lives, thus improving crop yield and the quality of crops.

Intelligent agriculture that is based on IoT started late in China.Recently, Wang *et al.*, (2022) reported one such system of application of an Intelligent Plant Protection Monitoring System where integration of a wireless lens, temperature and humidity sensor, intelligent information terminal, and probe rod to realize the collection of plant images and meteorological information. At the same time, a software based on the mobile terminal and the computer terminal was developed. The plant images and meteorological data are transmitted to the server through Wi-Fi transmission. Combined with the expert knowledge model, a solution is generated, and the user can identify the current diseases and pests and obtain solutions at any time. The system can remotely and automatically monitor and warn of mainstream diseases and pests of field crops such as rice and wheat and provide support for fine plant protection management (Fig.2). On the other hand, the present system has collected abundant data, which seems to be chaotic but contains great value and proper analysis and addition of a data pre-processing module is necessary before data analysis. The effective and accurate processing of data can provide a scientific basis for the automatic control and intelligent management of the environment.

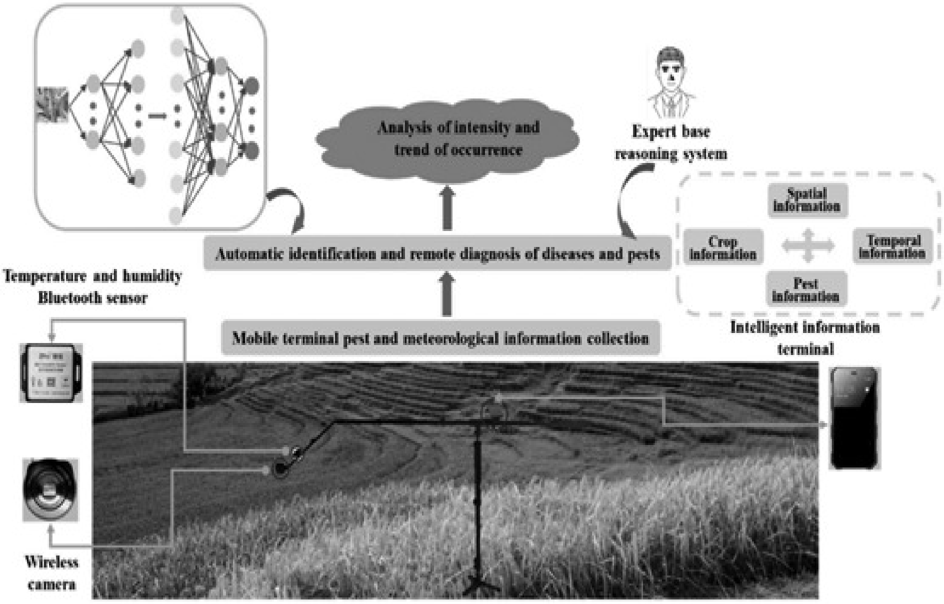

Figure 2. An overview of intelligent plant protection monitoring system (Source : Wang *et al.*, Agronomy, 2022, 12, 1046.doi.org/10.3390/agronomy12051046)

Conclusions and way forward :

Commendable breakthrough was done in the area of basic and applied researchesfor rice pest and disease management. But more focused research is required in some of the highly emerging and potential threatening pest and diseases of rice. Genome editing is potentially good techniques to develop resistantvariety. Host resistance may be good solution for endemic areas but pest monitoring, detection and application of appropriate molecules at proper time and doses are the key to manage crop pests. Here AI has good scope because the main concept of AI in agriculture is its flexibility, high performance, accuracy, and cost-effectiveness. The possible integration of AI with hyperspectral technology, nanotechnology and drone technology can make massive changes in crop disease management. However, there are still huge gaps in our knowledge of understanding in realistic way. Therefore, continuous focused research is required in straightaway to unravel the behaviour and fate of these potentially good techniques.

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