International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

# Innovations in Pest and Disease Management

***Shamik Dey[1*], Munmum Joshi[2], Nandini Pal[3], Bina Murmu[4], Dharmadas Kalindi[1], Gourab Ghosh[1], Rahul Nandi[1], Sohum Roy[1]***

[1.] Faculty of Agriculture, JIS University, Agarpara, Kolkata, West Bengal, India; [2.] Department of Fruit Science, College of Horticulture, Dr. Y.S. Parmar University of Horticulture and Forestry, Solan, India; [3.] Department of Zoology, Rishi Bankim Chandra College for Women, Naihati, West Bengal, India; [4.] Department of Zoology, Panihati Mahavidyalay, Kolkata, India.

*Corresponding Author

Corresponding Email: shamik.dey@jisuniversity.ac.in

**ABSTRACT:**

The increasing global population requires food that is of superior quality and contains few synthetic pesticide residues. In order to satisfy this need, new farming methods that enhance soil fertility, encourage ideal crop development, and boost crop resilience and resistance to pests and diseases must be created. The usage of organic soil improvers, biocontrol agents, insecticides, and semiochemicals can be enhanced with the use of precision farming. These sustainable farming methods, which emphasize increased crop yield and social inclusion, can be used in both small- and large-scale operations. While biopesticides, genetic engineering, and nanotechnology provide sustainable substitutes for traditional pesticides, emerging technologies such as remote sensing, drones, and artificial intelligence allow for early pest detection and monitoring. These technologies do, however, present socioeconomic, ethical, and regulatory obstacles. In order to fully fulfill these technologies' potential in reducing pest and disease challenges, this study emphasizes their revolutionary influence on crop productivity, quality, and sustainability. It also underscores the necessity for ongoing research, regulatory support, and stakeholder collaboration. This paper also presents the use of AI in the detection and prediction of pests and diseases, including the development and deployment of intelligent early warning systems and the application of data analysis, machine learning algorithms, and image recognition technologies.

**KEYWORDS:** Nanoparticles, Precision Agriculture, Remote Sensing, UAV, Artificial Intelligence.

## INTRODUCTION:

Global climate change-related uncertainties make managing pests and diseases more difficult; shifting climatic conditions may change the seasonality, range of distribution, and activity patterns of pests, making control more difficult and demanding.Farmers may limit and lessen the impact of pests and diseases on crops by using sophisticated monitoring systems to identify them early. Furthermore, farmers can employ proactive and focused management techniques by anticipating pest and disease threats with the aid of digital tools and predictive analytics. Farmers may optimize their pest and disease management strategies to reduce losses and increase yields by integrating data from pest populations, weather patterns, and crop health indicators. Technologies for precision agriculture present encouraging options for the early identification and focused control of crop diseases and pests. Precision agriculture uses cutting-edge sensors, data analytics, and automation systems to maximize outputs and optimize crop production inputs depending on temporal and spatial variability within fields (Chattopadhyay *et al.,* 2018). Precision agriculture technologies can facilitate site-specific interventions to reduce yield losses and environmental consequences, early pest and disease identification, and real-time crop health status monitoring in the context of crop protection (Weiss *et al.,* 2020). Additionally, genetic approaches, including genetically modified organisms (GMOs) and gene drives, are evaluated for their potential to disrupt pest life cycles effectively (Duguma B *et al*., 2012)

## TECHNOLOGICAL INNOVATIONS:

Significant financial losses in agriculture worldwide are caused by crop diseases.To stop the spread of disease and promote efficient field management techniques, crop health monitoring and early disease detection are crucial. Diagnostic technologies based on polymerase chain reaction (PCR) testing and serological techniques are frequently used in addition to crop disease identification, which is typically accomplished by scouting or field inspections. Prevalence (whether present or not) is evaluated at the field, farm, town, and/or landscape levels while conducting field inspections for early disease identification. This procedure is extensive, difficult, and time-consuming (Johansen et al. 2014). These restrictions on direct field inspection methods have prompted researchers to look at cutting-edge and unique systems that could provide crop health data quickly and affordably (Heim et al. 2019; Steward et al. 2019).

1. **Smartphone Image-Based Disease Detection**

A cutting-edge technique for image processing and object recognition, deep learning offers excellent classification accuracy for a range of agricultural diseases (Kamilaris and Prenafeta-Boldú 2018). AI-powered smartphone apps have the potential to prevent or reduce pest and disease outbreaks by warning farmers and speeding up disease diagnostics. Despite the fact that many farmers in underdeveloped nations lack access to these sophisticated technologies, new discoveries for infield crop disease diagnosis are made possible by growing Internet penetration, smartphone adoption, and offline models. Over 500 million Africans rely on cassava for their daily sustenance. Cassava is susceptible to a number of illnesses that result in greater yield losses. It is difficult for farmers (and even extension agents) to accurately identify the different illnesses.

1. **Aerial (UAV or Satellite) Image-Based Disease Detection**

The opportunity to collect high spatial and spectral resolution data, particularly for disease detection over fields and landscapes, is made possible by the rapid advancement of unmanned aerial vehicle (UAV) technology and the availability of inexpensive UAVs equipped with sensors. To better understand host-pathogen interactions, it is essential to be able to capture the crop phenotypic variations in this intricate multifaceted system (Steward et al. 2019). The integration of aerial picture information and AI-based techniques can give a reliable, high-throughput method for crop dis- ease detection under real-world settings (Boulent et al. 2019; Selvaraj et al. 2020).

2. **Nucleic Acid (NA) Sequence-Based Digital Surveillance Systems for Pathogens and Pests**

Utilizing pest and disease genetic data has a great chance of bolstering the current conventional surveillance methods. As a result of the application of high-throughput sequencing (HTS) technology to field diagnostics, more nucleic acid sequences are becoming available as data. Early warning identification of the introduction and possible spread of various pest and pathogen strains will be the most important use of genetic data. These technologies were initially modified for the study and identification of plant viruses in sweet potatoes and a few other crops (Kreuze et al. 2009; Adams et al. 2009).

3. **Remote Sensing**

Remote sensing technology has been extensively studied and applied for a variety of crop pests in numerous nations over the last few decades. Here are a few instances of insect pests that remote sensing is used to control.

- **Colorado Potato Beetle:** Colorado potato beetles (CPBs) can be identified via remote sensing and small unmanned aerial systems (sUAS) because low flight altitudes allow for the acquisition of photos with incredibly high spatial resolution. The area of CPB damage as determined by object-based image processing exhibited a strong association with the visual rating of damage. Object-based image processing based on high spatial resolution sUAS remote sensing can be used for early detection. Early detection of Colorado potato beetle (CPB) damage reduces the amount of insecticides needed in a field by providing additional options for precision integrated pest management (Hunt & Rondon, 2017).
- **Mustard Aphid:** Dutta et al. (2008) used satellite-based remote sensing data to model the geographical spread of aphids (*Lipaphis erysimi)* in Indian mustard. They made use of data from the National Oceanic and Atmospheric Administration's (NOAA) Operational Vertical Sounder (TOVS) and Television and Infrared Operational Satellites (TIROS) as well as near-surface meteorological parameters gleaned from field observations of pest infestation. The relationship between the peak aphid count and the TOVS cumulative air temperature at peak was found to be fitted by second-order polynomials at two test sites in India, Bharatpur and Kalyani. The regional level model was validated over a large area of a mustard-growing region for a range of sowing dates, surface air temperature, and specific humidity in order to show the spatial distribution of aphid growing severity zones and predict the dates of severe aphid infestation (peak population) at each grid level in the region.
- **Chilli Thrips:** Several multispectral vegetation indices have been used in the multispectral satellite pictures to try and differentiate between pest-affected and healthy chilli crops (Prabhakar et al., 2019). Of the spectral vegetation indices, the LSWI and NDWI were shown to be the two most important. LSWI was found to perform better than NDWI. Therefore, the LSWI was used to estimate the area affected by thrips and the degree of their infestation in the Kurnool District of Andhra Pradesh State, India, using satellite data.

## NANOTECHNOLOGY APPLICATIONS

**Principles of nanotechnology :**

4. The advantages of nanomaterials' small size, large surface area, and ease of attachment make them ideal for the efficient smart delivery of agrochemicals.
5. Unlike conventional pesticide formulations, where over 90% of the pesticides runoff within the surroundings and leave residue in agricultural goods during application.
6. Targeted delivery improves the efficacy of pesticides against plants, insects, and pathogens, increases solubility, disperses fat-soluble chemicals in aqueous solution, decreases the number of pesticides applied.
7. For a necessary amount of time and at a predetermined pace of release, the control delivery systems enable the active ingredient to be released gradually at the target spot.

### *The utilisation of nanomaterials for pest and disease management in agricultural*

Various insect pests can be controlled by using nanomaterials such as carbon, titanium dioxide, zeolites, silver, silica, copper, and alumina. Nanomaterial-based plant protection solutions, commonly referred to as nano-enabled pesticides, promise many benefits over conventional pesticide products while altering the risk profile or mode of action of existing poisons. Better insect species targeting, lower application rates, easier application, more efficacy, improved formulation features, and increased environmental safety are a few possible advantages.

- **Nanoscale silver**

  High surface area, extreme stability, and excellent dispersibility in aqueous solution characterize silver nanoparticles. Pesticides can be applied with fewer doses when coupled with metal-based nanoparticles. In a number of ornamental plants, (Rouhani *et al.,* 2012) confirmed that silver nanoparticles showed greater insecticidal action against the oleander aphid, *Aphis nerii.* Ag+ aqueous solution and more deaths were caused by gold nanoparticles based on pungam oil., whereas Ag+-AuNPs treatment aqueous solutions significantly increased food consumption and assimilation but decreased conversion and had an impact on *Olepa ricini* growth.

- **Nanoscalealumino-silicate**

  Chemical companies create insecticides at the nanoscale that work well. When insect hairs are exposed to sprayed aluminum-silicate nanotubes from plant surfaces, they aggressively groom and consume the pesticide-laced nanotubes. Nanotube-based pesticides have higher biological activity and are more environmentally friendly. Two stored grain insect pests, S. *oryzae* and R. *dominica*, were examined for insecticidal action, and it was found to be a cost-effective and efficient way to manage the pests after they caused death after three days of continuous exposure (Shamik and Rahul, 2024).

- **Magnetic nanoparticles**

  Using magnetic-based nanoparticles, systemic plant protection chemicals that only impact particular plant sections could be given to targeted locations. It may be possible to monitor the motion of internalized magnetic nanoparticles using external magnets with high power. In social insects, magnetic nanoparticles serve as geomagnetic sensors, and ferromagnetic resonance that is temperature dependent is known to occur (Shamik and Rahul, 2024).

- **Nano-Zinc**

  Numerous labs have investigated the antibacterial activity of zinc nanoparticles against plant diseases, much like they have Ag and Cu. Nano-Zinc inhibits bacteria, a variety of fungal pathogens, such as A. *alternata,* B. *cinerea,* F. *oxysporum, Mucor plumbeus, Penicillium expansum, Rhizoctonia solani, Rhizopus stolonifera*, and *Sclerotinia sclerotiorum*, as well as the nematode M. *incognita*, according to the majority of in vitro studies. More significantly, research in the field and in greenhouses has shown that nano-Zn suppresses disease. Using nano-Zn to treat bacterial infections has received more attention than treating diseases brought on by other pathogens. A new antibacterial light-activated $TiO_2$/Zn nanoparticle composite was developed by (Paret *et al.,* 2013a) using photocatalyst technology and nanotechnology to inhibit bacterial leaf spot on roses caused by a *Xanthomonas* sp.

- **Liposomes**

  One phospholipid bilayer and a spherical vesicle make up the special molecules known as liposomes. They come in a variety of sizes, but many are in the nano range and feature an empty inside that can hold antibacterial substances. Liposomes are utilized to encapsulate antimicrobial ingredients like chitosan and phenolic-containing plant extracts that inhibit gram-negative bacteria. Because of their long-term stability in water, the liposomes hold promise for use in crop irrigation treatments to prevent disease. Perez-´de-Luque *et al.,* 2012 actually discovered that amphotericin linked to liposomes created nanodisks that were effective in irrigation water at 10 µg/mL and postponed the onset of illness symptoms in chickpeas infected with F. *oxysporum f. sp. ciceris*.

## *BIOTECHNOLOGICAL APPROACHES*

- **Crygenes:**

  Particular pest classes are severely poisoned by insecticidal crystalline proteins (ICPs), which are produced by the Gram-positive soil bacteria *Bacillus thuringiensis* (Bt). According to Palma *et al.,* 2014, insect-resistant Bt crops exhibit insecticidal activity due to the genes encoding parasporal crystal protoxins. The generation of ICPs by transgenic plants has effectively led to the evolution of insect resistance. The procedure involves a protoxin protein that is soluble due to the larval midgut's alkaline pH and subsequently cleaved enzymatically into an active toxin. The peritrophic membrane, which covers the gut and binds to receptors in the midgut epithelium, causing holes in the epithelium, permits the poison to spread. The insect stops eating and dies in 2 to 3 days after its stomach becomes paralyzed. BG II is currently planted in 95% of India's cotton-growing land. BG II contains a variety of toxins, however compared to BG I, which only contains cry1Ac, cry1Ac and cry2Ab are more effective at controlling pests.

- **Gene editing**

  It is referred to as "switch hereditary qualities." A prerequisite for analyzing reverse genetic material is the capacity to alter the target species' DNA sequence. It is even possible to apply gene-editing techniques to decrease opposition and insect farming; for example, CRISPR gene editing was used in a helpful study to find pertinent gene targets in diamondback moths (Huang *et al.,* 2016). The goal of these gene-editing methods is to either lower vector populations by inhibiting female fruitfulness (Nandi, 2024) or switch a population by spreading a gene that impacts the ability to retain microbial life. But as these strategies get closer to flexible field application, important administrative, social, environmental, and specialist work still has to be prioritized.

## CHALLENGES AND PROSPECTS:

### *Challenges of innovations in pest and disease management:*

1. Increasing demands for total, safe and diverse foods to support the booming global population and its improving living standards.
2. Reducing production potential in agriculture due to competition for land in fertile areas and exhaustion of marginal arable lands.
3. Deteriorating ecology of agro-ecosystems and depletion of natural resources.
4. Increased risk of disease epidemics resulting from agricultural intensification and monocultures.
5. A lack of biological data can make it difficult to develop economically, environmentally, and socially sound crops production systems.

### *Prospect of innovations in pest and disease management :*

1. Development of pest-resistant crop varieties through advanced genetic engineering.
2. Application of AI and IoT for real-time pest and disease monitoring.
3. Use of biological control agents, such as beneficial insects and microbes.
4. Precision agriculture technologies for targeted pesticide application.
5. Integration of predictive analytics for early disease outbreak forecasting.
6. Adoption of environmentally friendly biopesticides and biofungicides.
7. Utilization of drones for large-scale pest surveillance and control.
8. Enhanced data sharing platforms for collaborative pest management strategies.
9. CRISPR gene-editing technology for pest population control.
10. Implementation of blockchain for traceability in pest management practices

## CONCLUSION:

With alternatives ranging from early detection to sustainable control, emerging technologies have enormous potential for managing pests and diseases in agriculture. However, overcoming ethical, legal, and financial obstacles is necessary for successful implementation. Simplifying approval procedures, encouraging responsible innovation, and guaranteeing fair access to new technologies all depend on cooperation between legislators, researchers, and industry partners. To properly use these technologies, farmers—especially smallholders—need to build capacity and share knowledge. Crop resilience, productivity, biodiversity, and ecosystem health can all be improved by taking a comprehensive strategy that combines ecological principles with technological improvements. A healthy agricultural future depends on ongoing investments in education, research, and policy assistance.

### REFERENCES:


1. Adams, I. P., Glover, R. H., Monger, W. A., Mumford, R., Jackeviciene, E., Navalinskiene, M., ... & Boonham, N. (2009). Next-generation sequencing and metagenomic analysis: a universal diagnostic tool in plant virology. *Molecular plant pathology*, *10*(4), 537-545.
2. Boulent, J., Beaulieu, M., St-Charles, P. L., Théau, J., & Foucher, S. (2019). Deep learning for in-field image-based grapevine downy mildew identification. In *Precision agriculture'19* (p. 8689). Wageningen Academic Publishers.
3. Chattopadhyay, D., Balachandra, Y., Ashoka, P., Pagire, K. S., Sahu, T. K., Panotra, N., ... & veer Singh, B. Precision Agriculture Technologies for Early Detection of Crop Pests and Diseases.
4. Dey S., Nandi R. "Application of nanotechnology in crop pest management- A review" . International Journal of Agriculture and Plant Science, Volume 6, Issue 3, 2024, Pages 61-67.
5. Duguma, B., Tegegne, A., & Hegde, B. (2012). Smallholder livestock production system in Dandi district, Oromia Regional State, central Ethiopia. *Read and write*, *20*, 25-6
6. Heim, R. H. J., Wright, I. J., Allen, A. P., Geedicke, I., & Oldeland, J. (2019). Developing a spectral disease index for myrtle rust (Austropuccinia psidii). *Plant Pathology*, *68*(4), 738-745.
7. Hunt Jr, E. R., & Rondon, S. I. (2017). Detection of potato beetle damage using remote sensing from small unmanned aircraft systems. *Journal of Applied Remote Sensing*, *11*(2), 026013-026013.
8. Huang, Y., Chen, Y., Zeng, B., Wang, Y., James, A. A., Gurr, G. M., ... & You, M. (2016). CRISPR/Cas9 mediated knockout of the abdominal-A homeotic gene in the global pest, diamondback moth (*Plutella xylostella*). Insect Biochemistry and Molecular Biology, 75, 98-106.
9. Kreuze, J. F., Perez, A., Untiveros, M., Quispe, D., Fuentes, S., Barker, I., & Simon, R. (2009). Complete viral genome sequence and discovery of novel viruses by deep sequencing of small RNAs: a generic method for diagnosis, discovery and sequencing of viruses. *Virology*, *388*(1), 1-7.
10. Matouskova, P., Marova, I., Bokrova, J., & Benesova, P. (2016). Effect of encapsulation on antimicrobial activity of herbal extracts with lysozyme. Food technology and biotechnology, 54(3), 304-316.
11. Nandi, R. (2024). Chapter-3 Application of Biotechnology in Entomology. ENTOMOLOGY, 51.
12. Palma, L., Muñoz, D., Berry, C., Murillo, J., & Caballero, P. (2014). Bacillus thuringiensis toxins: an overview of their biocidal activity. Toxins, 6(12), 3296-3325.

13. Paret, M. L., Palmateer, A. J., & Knox, G. W. (2013). Evaluation of a light-activated nanoparticle formulation of titanium dioxide with zinc for management of bacterial leaf spot on rosa 'Noare'. HortScience, 48(2), 189-192.
14. Pérez-de-Luque, A., Cifuentes, Z., Beckstead, J. A., Sillero, J. C., Ávila, C., Rubio, J., & Ryan, R. O. (2012). Effect of amphotericin B nanodisks on plant fungal diseases. Pest management science, 68(1), 67-74.
15. Rouhani M, Samih MA, Kalantari S. Insecticide effect of silver and zinc nanoparticles against *Aphis nerii* Boyer De Fonscolombe (Hemiptera: Aphididae). Chilean J Agric Res,2012:72(4):590-4.
16. Selvaraj, M. G., Vergara, A., Montenegro, F., Ruiz, H. A., Safari, N., Raymaekers, D., ... & Blomme, G. (2020). Detection of banana plants and their major diseases through aerial images and machine learning methods: A case study in DR Congo and Republic of Benin. *ISPRS Journal of Photogrammetry and Remote Sensing*, *169*, 110-124.
17. Weiss, M., Jacob, F., & Duveiller, G. (2020). Remote sensing for agricultural applications: A meta-review. *Remote sensing of environment*, *236*, 111402.