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AGRICULTURE FORUM FOR TECHNICAL EDUCATION OF FARMING SOCIETY

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Precision Entomology: Digital Tools for Pest Management

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INTRODUCTION

Precision Entomology (PE) is a new discipline of pest management that combines digital technologies, artificial intelligence, remote sensing and data analytics to digitally monitor, forecast, and manage insect pest populations at very high resolution with a very small environmental footprint. It is a component of PA closely related to the ecology of insect pests and their spatial and temporal dynamics which assists in developing site-specific, data-driven and sustainable pest management approaches.

The Need for Precision Entomology

Precision entomology is increasingly important for achieving effective and sustainable pest management in modern agriculture. Conventional practices often involve the excessive and indiscriminate use of insecticides, which accelerates the development of pest resistance and reduces the long-term effectiveness of chemical control. Repeated pesticide applications also contribute to environmental pollution, contaminate soil and water, and harm beneficial organisms such as pollinators and natural enemies. In many farming systems, delayed pest detection allows infestations to spread before control measures are initiated, resulting in greater crop damage and higher management costs. In addition, poor and inconsistent scouting techniques often fail to provide accurate information about pest distribution and population density. Precision entomology addresses these limitations by using sensors, drones, imaging tools, artificial intelligence, and data-based monitoring to detect pests early, map infestation hotspots, and support timely, targeted interventions.

Goal

The primary goal of precision entomology is to manage insect pests at the right time, in the right place, and in the right amount by employing digital tools and data-driven technologies. Sensors, drones, geographic information systems, remote sensing, and artificial intelligence help detect pest infestations early and identify specific hotspots within a field. This enables targeted application of insecticides and other control measures only where and when they are required, thereby improving pest-control efficiency, reducing chemical use and production costs, and minimizing environmental contamination.

Core Concept

The phrase “From field-wide spraying→ to site-specific pest management” captures a fundamental transition in contemporary agricultural practice:

Field-wide spraying (traditional approach): With traditional pest management, insecticides are sprayed evenly on the whole field whether pests are found in the entire field or not. This could potentially increase the use of chemicals, costs and environmental pollution.

Site-specific pest management (conventional practice): Precision entomology allows pest management to be conducted at a localized scale, such as in pockets of infestation in a field. Decisions are taken with the Help of digital tools like GPS, GIS, drones, sensors, and AI-based monitoring systems.

Key idea of the shift: Reduced pesticide usage Cost of production is less; Better environmental safety; and better pest control o better crop health and sustainability.

DIGITAL TOOLS USED IN PRECISION ENTOMOLOGY

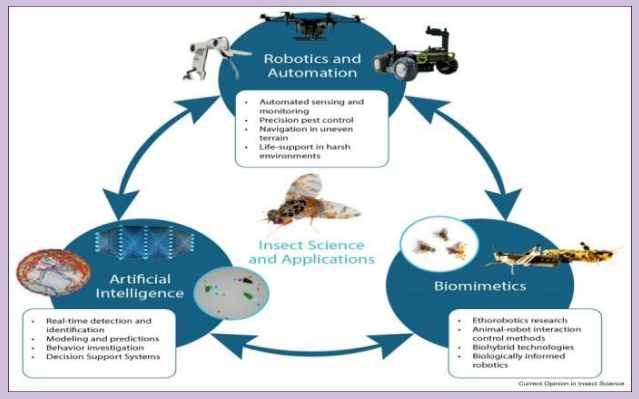
1. Remote Sensing (RS):
Remote Sensing employs satellite- and drone-based imaging techniques to track crop health and identify pest-induced issues. It serves to detect crop stress due to insect pests, to interprete vegetation dynamics observed by indices such as NDVI, and to identify early infestation areas before they are significantly affected.

2. Geographic Information System (GIS):
GIS has been applied for the spatial analysis of pest information. It enables the detection of pest distribution at the field scale, the identification of pest hotspots, and the elaboration of pest risk maps, all of which contribute to enhanced planning and more timely management of decisions.

3. GPS Technology:
GPS is utilized in precise tracking of a field location and through site-specific pest management. It can be seen in precision spraying systems, that help farmers spray pesticides exactly where they need to, which means less wastage and fewer or no environmental impacts.

4. Drones (UAVs):
Drones or Unmanned Aerial Vehicles (UAVs) are now being utilized for aerial pest scouting and monitoring crop condition from top. They are also used for spraying insecticides at specific points and for conducting surveys of vast or difficult-to-reach fields quickly and effectively.

5. IoT-Based Sensors:
IoT-based sensors to monitor environmental and field conditions, such as temperature, RH, dew point, leaf wetness, and number of insect traps. These data streams are very valuable for forecasting pest outbreaks and aiding in pest management in a timely manner. decisions.



SMART PEST MONITORING SYSTEMS

1. Smart Pheromone Traps:
Smart pheromone traps are high-tech monitoring devices with built-in sensors and cameras. They are able to collect, quantify and identify insect pests automatically and send the real-time information to mobile or cloud solutions allowing for continuous pest monitoring.

2. Light & Sticky Smart Traps:
The Light & Sticky Smart Traps are digital pest capturing devices that employ light or sticky materials to attract bugs. Embedded with AI-based recognition system for accurate identification of insect species, they assist in enhancing monitoring and evaluating pest.

3. Mobile-Based Scouting Apps:
Mobile scouting software enables farmers to send images of pest-affected crops while still in the field. These apps offer immediate pest diagnosis and suggest necessary control measures, so pest management is made easier and faster.

4. AI & Machine Learning Models:
Artificial Intelligence (AI) and Machine Learning (ML) models are applied to forecasting pest outbreaks, recognizing insect species, and decision support systems. For instance, ML models provide predictions for outbreaks of Helicoverpa armigera based on environmental variables temperature, humidity and host crop stage.

PRECISION PEST MANAGEMENT APPROACH

1. Site-Specific Pest Management (SSPM):

Site-Specific Pest Management implements pest control practices only at those places where the pest population is above the economic threshold level. Rather than broadcasting treatment over the whole field, application is limited to infested areas, making use of efficiency in spraying and reduction of unnecessary pesticide use.

2. Decision Support Systems (DSS):

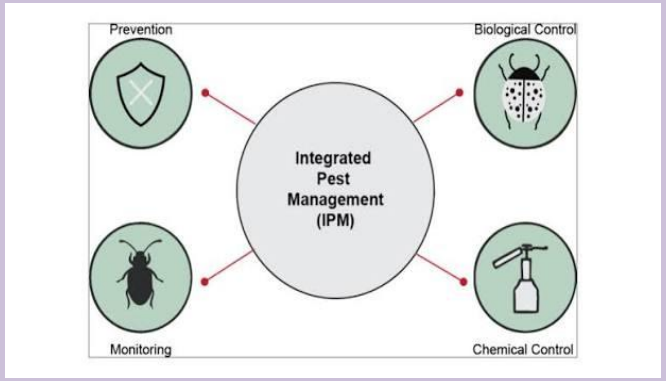
Decision Support System are computer-based tools that help farmers and agronomists to take better decisions regarding pest management. These systems recommend when to spray, which pesticide to use, and the dose to apply according to the field situation and pest conditions.

3. Variable Rate Technology (VRT):

The amount of pesticide applied can be tailored to the needs of each spot of the field, taking into account the intensity of pest infestation in different areas of the field, with the use of Variable Rate Technology. Such a targeted application procedure reduces chemical use significantly, typically by 20–60%, with an effective control of pests.

4. Integration with IPM:

By enhancing biological control monitoring, reducing reliance on chemical pesticides, and encouraging more environmentally sustainable and equitable pest management practices, precision entomology reinforces Integrated Pest Management (IPM).



FUTURE SCOPE & CHALLENGES

- AI-powered autonomous spraying robots
- Satellite-based pest forecasting systems
- Blockchain for pest data management
- 5G-enabled real-time farm monitoring
- Fully automated smart pest control systems

Challenges

- High initial investment cost
- Lack of technical knowledge among farmers
- Limited rural digital infrastructure
- Data accuracy and interpretation issues
- Small farm fragmentation

CONCLUSION

Precision Entomology represents a major paradigm shift in insect pest management, meaning a fundamental change from traditional practices to modern technology-driven approaches. By integrating digital tools, artificial intelligence (AI), and smart monitoring systems, it enables more accurate detection, prediction, and control of insect pests. This improves the efficiency of pest management while reducing the unnecessary use of chemical pesticides, making the system more sustainable and environmentally safe. Overall, it plays a crucial role in advancing next-generation smart agriculture, where data and technology guide precise and timely farming decisions.