AgroScience Today

Popular Article

e-ISSN: 2583-0147

Volume 7 Issue 8
Page: 1317 - 1320

Smart Traps for Smartest Pest Management - Bringing Technology into the Field

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Published on: August 31, 2026

ABSTRACT

Insect pest monitoring is one of the most important steps in effective pest management, as timely detection can prevent pest populations from reaching damaging levels. Conventional monitoring methods such as visual scouting, sticky traps, light traps and pheromone traps are useful. Still, they often depend on frequent field visits and manual identification and counting of insects. Recent advances in artificial intelligence (AI), computer vision, sensors, wireless communication, and the Internet of Things (IoT) are transforming traditional traps into smart traps. These systems can automatically detect, photograph, identify, and count insects while transmitting data to farmers or researchers in near real time. Such technology can support early pest detection, improve decision-making and reduce unnecessary pesticide applications. This article highlights the development of smart insect traps, their working principles, applications in pest monitoring, selected case studies and their potential role in precision pest management.

INTRODUCTION

Before a pest becomes a visible problem in a crop, its population often begins increasing silently. By the time farmers notice widespread leaf damage or fruit infestation, valuable time for intervention may already have been lost. This makes early and accurate pest detection a critical component of integrated pest management (IPM). Traditionally, entomologists and farmers have relied on methods such as visual scouting, sweep nets, sticky traps, light traps and pheromone traps to monitor pest populations. These methods remain valuable and are widely used. However, monitoring large agricultural areas manually can be time-consuming, labour-intensive and dependent on the skill of the observer. Counting and identifying insects from hundreds of traps can also become difficult when several species are present.

This is where technology is beginning to change the way we monitor insects. A conventional trap can tell us that insects are present. A smart trap can potentially tell us what insect is present, how many are there, when their numbers are increasing and, in some systems, where the problem is occurring. By combining traps with cameras, sensors, AI and wireless communication, insect monitoring is moving from periodic field observation towards continuous, data-driven surveillance.

FROM TRAPPING TO TRACKING

The basic principle of a smart trap is not very different from that of a conventional trap. The major difference is what happens after the insect enters the trap. A smart trap may contain a camera that captures images of trapped insects. Computer-vision algorithms can then analyse these images and distinguish target insects from other organisms or background material. Some systems can automatically count insects and record the date and time of capture. The information can be transferred through wireless networks to a computer, smartphone or cloud-based platform.

This creates a continuous flow of information:

Trap → sensor/image → AI-based identification → Insect count → Data transmission → Pest warning → Management decision

For example, if the number of a particular moth species suddenly increases in a field, the farmer could receive an alert and inspect the crop before serious damage occurs. This approach is particularly useful for pheromone-based monitoring, where traps are already designed to attract specific pest species. Instead of requiring a person to visit each trap and manually count insects, automated systems can perform much of the monitoring work.

WHAT MAKES A TRAP "SMART"?

Several technologies can be combined to create a smart insect trap:

Computer vision	Cameras capture images of insects, while image-processing techniques help detect and classify them.
Artificial intelligence	Machine-learning and deep-learning models can be trained using insect images to recognize particular pest species.
Sensors and IoT	Wireless sensors allow trap data to be transmitted remotely, reducing the need for frequent physical inspection
Cloud-based monitoring	Data from multiple traps can be stored and analysed centrally, allowing researchers and farmers to observe pest trends over time.
Mobile alerts	Some systems can provide notifications when pest numbers cross a predefined threshold, allowing quicker field action.

Together, these technologies can transform a simple trap into a remote pest-monitoring station.

CASE STUDIES

Target pest	Technology	Key findings	Reference
Red turpentine beetle (*Dendroctonus valens*)	Pheromone trap + camera + RTBnet deep learning	Automatically detected and counted *D. valens* inside pheromone traps using deep learning, with successful discrimination from non-target beetles.	Sun et al., 2018;
Fruit flies	Remote trap + edge deep learning + object detection	Enabled real-time insect detection directly on the smart trap using edge-based deep learning.	Phạm et al., 2021
Codling moth	Trap images + deep-learning-based detection and counting	Automatically detected and counted moths from trap images, reducing the need for manual monitoring.	Ding et al.,2016;
Fruit flies & fall armyworm	IoT smart trap + camera + YOLOv8x	Achieved accurate automatic detection of fruit flies and fall armyworm using YOLOv8x-based smart traps.	Hakim et al., 2025;

WHY SMART TRAPS MATTER

Smart traps are not simply about replacing humans with machines. Their real value lies in helping humans make better and faster decisions. Continuous monitoring can help identify pest population increases before they become severe. It can also contribute to more precise pesticide application by helping determine whether, when and where treatment is actually required. This fits well with the principles of Integrated Pest Management (IPM), where pesticides are used judiciously and only when economically justified. Smart monitoring may therefore contribute to Early detection of pest outbreaks and reduced labour required for trap inspection, Faster insect identification and counting, more frequent and reliable monitoring, Better understanding of pest population dynamics, Targeted pesticide application, reduced unnecessary pesticide use, and improved decision-making in precision agriculture.

CHALLENGES AHEAD

Despite their promise, smart traps are not a perfect solution. Insects can be difficult to distinguish from one another, particularly when species have similar shapes, colours or sizes. Dust, plant debris, overlapping insects, poor lighting and damaged specimens can also affect image recognition. Another important challenge is the availability of high-quality insect image datasets. An AI model trained using images from one environment may not perform equally well under different field conditions.

Cost, internet connectivity, power supply and maintenance can also limit adoption, particularly for small and resource-limited farmers. Therefore, future smart traps need to become affordable, robust, energy-efficient and easy to operate. Most importantly, AI should support, not completely replace, entomological expertise. Correct pest identification and management recommendations still require biological knowledge and field validation.

CONCLUSION

The humble insect trap is entering a new phase. What once served mainly as a tool for catching and counting insects can now become a digital window into pest populations. By combining pheromones with cameras, artificial intelligence, sensors and wireless communication, smart traps offer a promising approach for faster and more precise pest monitoring. The future of pest management may not depend on simply catching more insects, but on understanding their numbers, behaviour and population changes in real time. As these technologies become more affordable and reliable, smart traps could become an important component of precision agriculture and integrated pest management.

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