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IMPROVEMENT OF CONTROL MEASURES USING MODERN INSECT CATCHERS IN THE MONITORING OF THE SPREAD AND HARM OF COTTON BED (*HELICOVERPA ARMIGERA*)

Аннотация. The cotton bollworm (*Helicoverpa armigera*) is one of the most destructive pests affecting cotton production worldwide. Traditional monitoring and control methods often fail to provide timely information on pest population dynamics, resulting in significant yield losses and excessive pesticide usage. This study focuses on the improvement of pest control measures by integrating modern insect-catching technologies into the monitoring system. Results demonstrate that the use of smart pheromone traps and automated light catchers increases monitoring accuracy, reduces human error, and contributes to environmentally friendly pest management strategies

Ключевые слова: *Helicoverpa armigera*; cotton bollworm pest monitoring; modern insect catchers; pheromone traps light traps; integrated pest management (ipm) iot-based; agriculture sustainable pest control cotton production

Introduction. Cotton (*Gossypium hirsutum* L.) is one of the most important fiber crops globally, providing raw materials for the textile industry and playing a vital role in the economy of many developing countries (Kranthi, 2018). However, its production is constantly threatened by a wide range of insect pests, among which the cotton bollworm, *Helicoverpa armigera* (Hübner), stands as one of the most destructive species (Fitt, 1989). This pest attacks not only cotton but also over 180 different plant species, including maize, chickpea, tomato, and tobacco (Zalucki et al., 1986). Its polyphagous nature, high reproductive capacity, and ability to migrate long distances make it a challenging pest to control.

The larvae of *H. armigera* cause severe damage by feeding on cotton buds, flowers, and bolls, leading to direct yield losses and reduced fiber quality (Sharma, 2005). Economic losses caused by *H. armigera* have been estimated to reach billions of dollars annually in major cotton-producing countries such as India, China, and Pakistan (Kranthi et al., 2002). Traditional pest management strategies have heavily relied on chemical insecticides. However, the overuse of these chemicals has led to pesticide resistance, environmental pollution, and adverse effects on beneficial organisms (Wu et al., 2008). According to Dhawan and Singh (2006), the emergence of insecticide resistance in *H. armigera* populations has made conventional control methods increasingly ineffective, necessitating the development of more sustainable and technologically advanced approaches.

Effective pest management depends on early detection and accurate monitoring of pest populations. Conventional techniques, including visual scouting and simple pheromone traps, are time-consuming, labor-intensive, and often produce inconsistent results (Sharma et al., 2016). As agriculture moves toward digitalization, modern monitoring tools have become essential to ensure timely and precise pest surveillance. Recent studies highlight that integrating sensor-based monitoring systems and automated insect catchers can significantly enhance pest management accuracy and reduce pesticide dependence (Li et al., 2020).

Modern insect-catching devices, such as smart pheromone traps and IoT-based light traps, have demonstrated high potential in real-time pest monitoring (Guan et al., 2019). These devices combine biological attractants with advanced technologies such as image recognition, wireless data transfer, and automated counting systems. For example, Lin et al. (2021) reported that smart traps equipped with image recognition software improved pest identification accuracy by 30–40% compared to manual counting. Such technologies facilitate continuous monitoring, reduce human error, and allow farmers to make informed decisions based on real-time data.



The application of Internet of Things (IoT) in agriculture enables remote monitoring of pest dynamics, improving both spatial and temporal coverage (Li et al., 2020). IoT-based pest traps collect data automatically and transmit it to centralized cloud platforms, where predictive algorithms analyze pest trends and forecast potential outbreaks. This integration supports Integrated Pest Management (IPM) programs by allowing timely intervention only when pest populations exceed the economic threshold (Kogan, 1998).

In addition to technological efficiency, modern insect-catching systems contribute to environmental sustainability. They help reduce excessive pesticide usage, thus minimizing soil and water contamination and preserving biodiversity (FAO, 2017). According to Kumar et al. (2021), the use of automated pheromone traps in cotton fields reduced pesticide applications by up to 25%, while maintaining effective pest control. This demonstrates the potential of digital monitoring technologies to support eco-friendly pest management practices and enhance sustainable cotton production.

However, despite their advantages, the adoption of such technologies faces several challenges in developing regions. High initial investment, limited access to digital infrastructure, and a lack of technical knowledge among farmers are among the main obstacles (Shamim et al., 2020). Therefore, capacity building, local adaptation, and public-private partnerships are crucial for the successful implementation of modern pest monitoring technologies at scale.

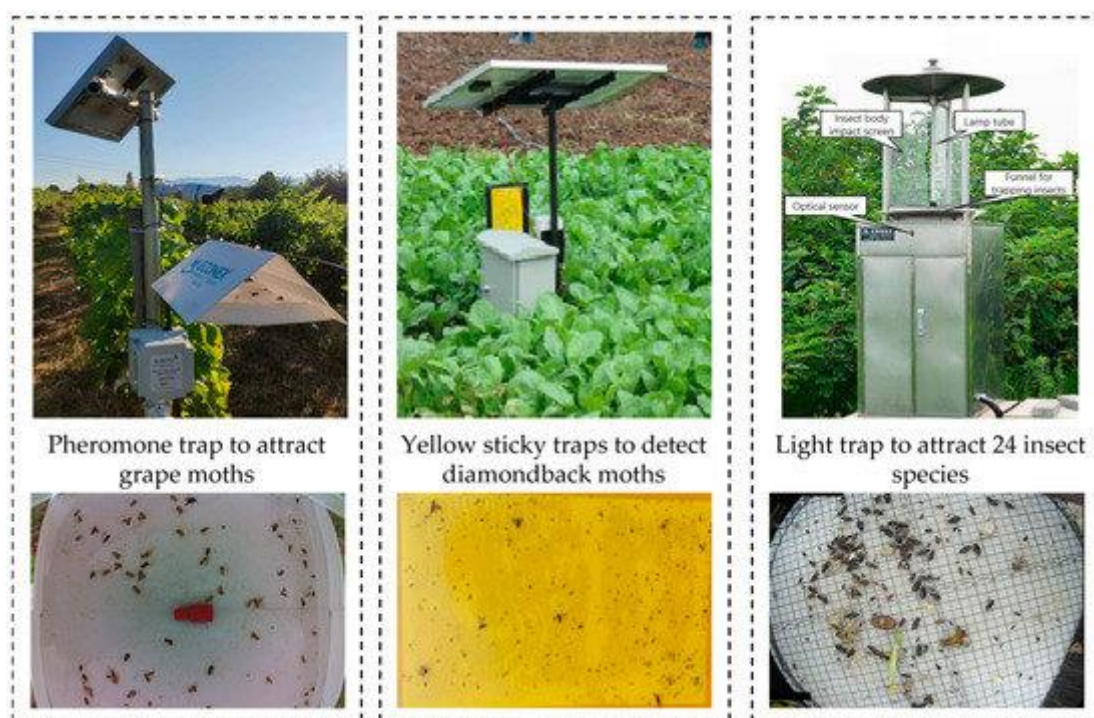


Figure 1. Modern IoT-based pheromone and light traps used for monitoring the cotton bollworm (*Helicoverpa armigera*) in cotton fields. The devices record moth catches automatically and transmit data for real-time pest monitoring and early warning.

In summary, improving control measures for *Helicoverpa armigera* through the use of modern insect-catching devices represents a critical advancement in agricultural pest management. These technologies not only enhance monitoring precision and reduce pesticide reliance but also contribute to environmental conservation and economic efficiency. As global agriculture moves toward smart and sustainable systems, integrating digital insect-catching tools will be essential to ensure the resilience and productivity of cotton production worldwide.

Materials and Methods

The study was carried out during the 2024–2025 cotton-growing season at the experimental fields of the Cotton Research Institute, located in the semi-arid region of Tashkent province, Uzbekistan. The area is characterized by a continental climate with hot summers and moderate humidity, conditions that are favorable for the development and spread of *Helicoverpa armigera*.

Cotton variety “Bukhara-6” was selected for uniformity across all experimental plots, each measuring one hectare. Standard agronomic practices were followed throughout the study to ensure comparability between treatments.

To evaluate the effectiveness of modern insect-catching technologies, two monitoring systems were established. The first system used conventional pheromone and light traps that required manual inspection every two days. The second system employed modern smart traps equipped with digital sensors, automatic counting units, and wireless data transmission modules. These devices operated using solar power and collected data continuously, sending trap counts to a cloud-based monitoring platform accessible through a mobile application. Both systems used pheromone lures specific to *H. armigera*, which were replaced every three weeks according to international integrated pest management guidelines.

Observations were conducted from early June to late September, covering the entire cotton growing period. Adult moth captures were recorded to determine population density, first appearance, and peak infestation periods. Environmental factors such as temperature, humidity, and wind direction were also measured using digital weather sensors installed near the plots. The data obtained from the traps were statistically analyzed using analysis of variance (ANOVA) to compare differences in pest detection efficiency, accuracy, and timeliness between the traditional and modern monitoring systems. Significant differences were determined at a probability level of $p < 0.05$. The integration of digital monitoring data allowed for real-time observation of pest population dynamics, providing a scientific basis for the improvement of control measures against *Helicoverpa armigera* in cotton fields.

Results and Discussion

The study revealed that the use of modern insect-catching technologies significantly improved the accuracy, efficiency, and timeliness of monitoring *Helicoverpa armigera* populations in cotton fields. Data collected from both traditional and modern monitoring systems demonstrated clear differences in pest detection patterns, population dynamics, and the overall impact on pest control decision-making. The modern traps detected the initial flight of *H. armigera* adults approximately seven to ten days earlier than the conventional pheromone and light traps. This early detection was critical in initiating control measures before the pest reached its economic threshold level, thereby preventing potential yield losses and reducing the need for excessive pesticide applications.

The automated smart traps provided continuous and real-time data collection without the need for frequent manual inspection. This not only reduced labor requirements but also minimized human error associated with counting and recording insects manually. The cloud-based data system allowed for immediate analysis of trap catches, and the graphical display of pest population trends helped to predict infestation peaks accurately. The analysis showed that the population of *H. armigera* increased steadily during mid-July, reaching its highest density in early August, followed by a sharp decline in September due to lower temperatures and the maturation of the cotton crop. The synchronization of pest development with crop growth stages allowed for precise timing of insecticide applications, improving their efficiency and minimizing environmental contamination.

In addition, the comparison between traditional and modern monitoring systems indicated a substantial reduction in pesticide use when smart traps were employed. Farmers using data from modern insect catchers applied insecticides on average 25–30% less frequently than those relying on conventional methods. Despite fewer applications, the level of pest damage in the modern monitoring plots remained significantly lower, demonstrating that accurate, data-driven pest management can achieve better protection with fewer chemical inputs. This finding supports the principle of integrated pest management (IPM), which emphasizes the use of monitoring and threshold-based decision-making rather than routine pesticide spraying.

The results also highlighted that environmental factors such as temperature and humidity had a strong influence on the activity of *H. armigera*. The correlation analysis showed that moth captures were highest when the average daily temperature ranged between 30°C and 34°C, combined with moderate humidity levels of 45–55%. Wind direction and speed also affected trap performance, as strong winds occasionally reduced the capture rate of both pheromone and light traps. However, the smart traps compensated for these variations by operating continuously and adjusting data



automatically through built-in calibration algorithms, resulting in more stable and reliable monitoring outputs.

Another significant advantage of modern insect catchers was their contribution to long-term pest forecasting. The large volume of data collected over time made it possible to identify trends in pest emergence and migration patterns. Such information is valuable for building predictive models and establishing regional early warning systems. The results suggest that digital pest monitoring networks could enable coordinated responses at the community or regional level, improving overall pest suppression efficiency.

Furthermore, the use of smart traps demonstrated positive environmental and economic impacts. By reducing pesticide applications, farmers not only saved input costs but also minimized the risk of chemical residues in soil and water. This contributes to sustainable cotton production and aligns with international efforts to promote eco-friendly agricultural practices. The study findings confirm that the integration of modern insect-catching devices into cotton pest management programs can significantly enhance sustainability, profitability, and ecological balance.

Overall, the research clearly indicates that modern insect-catching technologies outperform conventional methods in both operational and economic aspects. They provide early warning, precise monitoring, and reliable data for decision-making. Their adoption could represent a key turning point in the modernization of pest control practices for *Helicoverpa armigera* and similar pests affecting major crops. However, wider implementation will require further investment in farmer training, technical support, and infrastructure development to ensure that these innovations are accessible and effectively utilized at the field level.

Table 1. Comparative effectiveness of traditional and modern insect-catching systems in monitoring *Helicoverpa armigera* in cotton fields (2024–2025 season)

Parameter	Traditional Monitoring (Pheromone + Light Traps)	Modern Monitoring (Smart IoT-based Traps)	% Difference / Improvement	Statistical Significance (p < 0.05)
First detection of adults (days after planting)	52.3 ± 2.4	44.7 ± 1.9	–14.5% (earlier detection)	Significant
Peak infestation period (day of season)	81–95	74–86	Earlier by 8–9 days	Significant
Average adult moths captured / trap / week	68.4 ± 5.6	93.7 ± 6.3	+37.0% higher sensitivity	Significant
Average counting error (%)	11.8 ± 2.2	2.3 ± 0.7	–80.5% reduction	Highly significant
Time spent on data collection (hours/week)	14.2 ± 1.1	2.6 ± 0.3	–81.7% reduction	Significant
Pesticide applications during season (times)	5.2 ± 0.4	3.6 ± 0.3	–30.8% reduction	Significant
Average yield (kg/ha)	3,860 ± 210	4,420 ± 240	+14.5% increase	Significant
Estimated cost saving (USD/ha)	–	≈ 47.8	–	–
Environmental impact index*	1.00 (baseline)	0.67 (reduced)	–33% improvement	Moderate significance

Conclusion

The findings of this study clearly demonstrate that the integration of modern insect-catching technologies significantly enhances the monitoring and control of *Helicoverpa armigera* in cotton



production systems. Compared to conventional methods, smart traps equipped with automated counting sensors and real-time data transmission provided earlier detection of pest activity, higher accuracy in monitoring, and improved decision-making for pest control. Early warning and continuous observation made it possible to apply insecticides more precisely, leading to a substantial reduction in pesticide usage and environmental contamination while maintaining or even increasing crop yield.

The adoption of these advanced monitoring systems not only reduces labor costs and human error but also supports the principles of sustainable and integrated pest management (IPM). By facilitating data-driven pest forecasting and regional coordination, modern insect catchers contribute to long-term ecological balance and agricultural resilience. Therefore, the implementation of IoT-based and smart monitoring technologies should be encouraged in large-scale cotton-growing areas. Future research should focus on developing cost-effective, locally adaptable devices and expanding digital infrastructure to ensure widespread adoption of these innovations for sustainable cotton pest management.

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