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# GENETIC RESISTANCE OF TRANSGENIC *BT*-COTTON AGAINST BOLLWORM (*HELICOVERPA ARMIGERA,* NOCTUIDAE*,* LEPIDOPTERA) IN UZBEKISTAN

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## SUMMARY

Cotton is vital to Uzbekistan's economy; however, its production sustains severe effects from the bollworm (*Helicoverpa armigera*). This destructive pest damages the plant's reproductive parts, causing significant losses in seed cotton yield and fiber quality. Traditional reliance on chemical insecticides has led to pesticide resistance, ecological disruption, and environmental pollution, necessitating sustainable alternatives. Genetically modified *Bt*-cotton, expressing *Bacillus thuringiensis* toxins, offers an effective strategy by providing inherent genetic resistance against bollworm larvae. *Bt* cotton occurred as globally successful in reducing dependency on chemicals, and its efficacy depends on the local agroecological conditions. The data on the entomological effectiveness of *Bt*-cotton varieties remains limited in Uzbekistan. The potential study's novelty lies in its field-based evaluation of transgenic varieties under specific agroclimatic conditions of Uzbekistan, focusing on pest infestation intensity and genotypic resistance. The practical significance of this research contributes to the development of integrated pest management (IPM) strategies. By reducing dependency on chemical pesticides and improving environmental safety, this study aimed to enhance the long-term sustainability of cotton production in Uzbekistan.

**Keywords:** *Bt*-cotton, *Helicoverpa armigera*, genetic resistance, entomological evaluation, integrated pest management, sustainable crop protection, Uzbekistan

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**Key findings:** Insect pests of different crops provided uneven distribution across the different regions of Uzbekistan, with species diversity and population density varying by agroecological zones and cropping seasons. The highest pest activity resulted in lowland areas during spring and summer.

## INTRODUCTION

In agricultural productivity and sustainable food systems, insect pests remain a major limiting factor worldwide. These pests cause significant yield losses, reduce crop quality, and increase the cost of production, thereby posing serious economic and ecological challenges. Agricultural insect pests belong to various taxonomic groups, including Lepidoptera, Coleoptera, Hemiptera, Orthoptera, and Diptera, each characterized by specific biological and adaptive features that allow them to thrive under diverse agroecosystems (Pedigo and Rice, 2015; Dent and Binks, 2020; Hill, 2021; Sharma *et al*., 2022).

Insect pests' population dynamics and distribution are largely because of climatic conditions, landscape diversity, and crop management practices in Uzbekistan. The country's agroecological zones varied from irrigated lowlands to steppe, semidesert, and mountainous foothill regions, which develop heterogeneous habitats that support a wide spectrum of pest species. Intensification of agriculture, expansion of irrigation networks, and dominance of monocropping systems have contributed to considerable variations in pest ecology, including shifts in seasonal development, host-plant utilization, and outbreak frequency (Kurbanov *et al*., 2022; Tursunov and Karimov, 2023).

Seasonal variability plays a critical role in regulating pest population and activity. Most of the economically important insect pests enunciated higher population levels during spring and summer, when favorable temperature and moisture conditions accelerate their reproduction and development. Lowland and intensively cultivated areas proved particularly susceptible to pest outbreaks due to continuous crop availability and stable microclimatic conditions that further boost insect pest survival and dispersal.

Therefore, a comprehensive understanding of pest biodiversity, spatial distribution, and seasonal dynamics is crucial for the development of effective and environmentally safe pest management strategies. Combining ecological field studies with analytical approaches can provide a sound foundation for sustainable crop protection from insect pests. Recent studies emphasized that strengthening ecological literacy and analytical thinking contributes to improved interpretation of biological processes and supports evidence-based decision-making in agricultural pest management.

In this context, a growing need to shift from chemically intensive pest control methods toward integrated, environmentally safe management strategies is essential. Integrated pest management (IPM) combines biological, ecological, agronomic, and technological approaches to regulate pest populations while minimizing negative effects on non-target organisms and ecosystems. The IPM with effective implementation requires detailed knowledge of pest species composition, seasonal dynamics, host-plant relationships, and regional ecological conditions (Dent and Binks, 2020; Pedigo and Rice, 2015) (Tables 1 and 2).

Recent advances in pest monitoring, including precision agriculture technologies, remote sensing, and data-driven decision support systems, have considerably strengthened the ability to assess pest population trends and forecast outbreaks. These tools enable timely and targeted interventions, reducing unnecessary pesticide application and supporting sustainable crop protection. Furthermore, habitat management practices, such as crop diversification, conservation of natural enemies, and ecological engineering, have gained recognition as viable components of modern IPM frameworks (Gurr *et al*., 2017; Bravo *et al.,* 2011).

**Table 1.** Major crop pest species and regional abundance.

| Pest species | Family | Lowlands (n = 742) | Steppe/Semi-desert (n = 611) | Mountain foothills (n = 902) | Dominant host crops |
|---|---|---|---|---|---|
| *Helicoverpa armigera* | Noctuidae | 265 (36%) | 112 (18%) | 145 (16%) | Cotton, tomato |
| *Spodoptera exigua* | Noctuidae | 138 (19%) | 95 (16%) | 112 (12%) | Cotton, vegetable |
| *Aphis gossypii* | Aphididae | 82 (11%) | 67 (11%) | 95 (11%) | Cucurbits, legumes |
| *Liriomyza trifolii* | Agromyzidae | 56 (8%) | 44 (7%) | 72 (8%) | Vegetable crops |
| *Bemisia tabaci* | Aleyrodidae | 47 (6%) | 53 (9%) | 60 (7%) | Cotton, tomato |
| Others (15 species) | Multiple | 154 (21%) | 240 (39%) | 418 (46%) | Various crops |

**Table 2.** Seasonal dynamics of key pests.

| Pest species | Peak Activity | Zone | Damage observed (%) |
|---|---|---|---|
| *Helicoverpa armigera* | June-July | Lowlands | 35%–45% |
| *Spodoptera exigua* | May-June | Lowlands, steppe | 15%–20% |
| *Aphis gossypii* | June-August | All zones | 10%–15% |
| *Liriomyza trifolii* | June-July | Foothills, lowlands | 8%–12% |
| *Bemisia tabaci* | July-August | Steppe, lowlands | 5%–10% |

The region-specific pest management strategies appeared particularly relevant under the agroecological conditions of Uzbekistan, which has diverse climatic zones and intensive irrigation systems. Field-based ecological studies provide valuable empirical data essential for adapting IPM approaches to local environments and cropping systems. Such types of studies both support sustainable agricultural development and considerably contribute to strengthening scientific capacity and ecological literacy in the crop-related community.

Therefore, comprehensive investigations based on pest biodiversity, spatial distribution, and ecological adaptation were crucial for improving pest regulation strategies. Integrating scientific research with educational and analytical frameworks enhances interdisciplinary understanding and supports the development of resilient and eco-friendly agricultural systems capable of responding to ongoing environmental and climatic challenges.

## MATERIALS AND METHODS

### Study procedure

Field surveys conducted across the major cotton-growing regions of Uzbekistan took over a three-year period (2021–2024). Sampling sites included irrigated lowlands, steppe and semi-desert zones, and mountain foothills, representing diverse agroecological conditions. Insect samples' collection used sweep nets, pheromone traps, light traps, and direct plant inspections. Collected insect specimens underwent identification to the species level using standard taxonomic keys, with voucher specimens preserved for reference.

In addition to field observations, laboratory analyses transpired to assess pest developmental stages, reproductive rates, and damage severity. Historical pest records and annual reports associated with regional agricultural research centers also entailed reviews to complement the field data.

The study chose sampling locations across different agroecological regions of Uzbekistan to capture variation in climate, irrigation regimes, and crop management practices. These environmental and agronomic factors became considerations during data collection and analysis because of their potential influence on pest population dynamics.

### Statistical analysis

The conduct of data analysis used SPSS v.26 and R software. Species abundance, diversity indices (Shannon-Wiener and Simpson), and

seasonal fluctuations received calculations. Correlations between pest populations, host plants, and environmental factors also entailed evaluation using Pearson correlation and regression analyses. Spatial distribution maps' generation used GIS tools to visualize pest hotspots and regional patterns.

## RESULTS AND DISCUSSION

Overall, the study survey recorded 34 key insect pest species across 18 genera and 12 families. Bollworm (*Helicoverpa armigera*) and beet armyworm (*Spodoptera exigua*) were predominant insect species, with Shannon-Wiener diversity indices peaking in irrigated lowlands (2.85). Previous studies by Kurbanov *et al*. (2022) have also similarly identified these insect species as primary drivers of economic losses in the cotton fields of Central Asia, confirming that Lepidopteran dominance is a recurrent pattern observed in previous regional studies.

Pest abundance significantly varied among the agroecological zones, and the highest population densities resulted in irrigated lowlands. The susceptibility linked to intensive irrigation and monoculture cropping aligns with ecological theories of resource-rich environmental exploitation. Dent and Binks' (2020) findings revealed that stable agricultural ecosystems inherently lower the natural resilience of crops, while Kogan and Jepson (2020) validated that resource stability in lowlands acts as a crucial catalyst for population outbreaks.

Seasonal dynamics disclosed that pest activity peaks coincided with critical crop growth stages, specifically June-July for *H. armigera* and May-June for *S. exigua* (Figure 1). Previous research also supported these results, suggesting that precise temporal synchronization is the key factor in optimizing intervention timing in integrated pest management (Omonov *et al*., 2023). Furthermore, Chen *et al*. (2021) highlighted that such types of seasonal patterns had increasing control from regional climatic shifts.

Host-plant associations and population-density correlations ($r$ = 0.68–0.79, $P$ < 0.05) further underscored the importance of habitat manipulation. In alignment with these results, Omonov *et al*. (2025) reported that host-plant availability directly dictates Lepidopteran density. Gurr *et al*.'s (2017) findings emphasized that ecological engineering through intercropping is a management practice supported by published research to suppress the pest growth.

The economic analysis confirmed that crop yield losses due to *H. armigera* reached up to 45% (Figure 2). The implementation of *Bt*-cotton cultivars combined with biological control could mitigate these losses by 30%–35%. Pedigo and Rice's (2015) studies have established that integration of biotechnological resistance with biological agents has emerged to be the most sustainable economic strategy. Additionally, Pimentel (2022) documented that such multifaceted approaches considerably enhanced the long-term crop protection efficiency.

Overall, the presented study provides baseline data on pest biodiversity and ecological dynamics, supporting the development of resilient and eco-friendly agricultural systems. The results enunciated that insect pest populations in Uzbekistan gained influence largely from regional agroecological conditions, crop type, and seasonal factors. The predominance of Lepidopteran pests, particularly *Helicoverpa armigera* and *Spodoptera exigua*, aligns with previous reports exhibiting their major economic impact on cotton and vegetable crops in Central Asia (Kurbanov *et al*., 2022; Tursunov and Karimov, 2023).

The observed variations in species diversity and abundance across the irrigated lowlands, steppe zones, and mountain foothills further emphasized the role of habitat heterogeneity and crop management practices. Lowland regions with intensive irrigation and monoculture cropping were noticeably the most susceptible to the highest insect pest pressure, consistent with ecological theory predicting greater pest survival and reproduction in stable, and resource-rich environments (Dent and Binks, 2020; Kogan and Jepson, 2020). Furthermore, research confirmed that the cropping patterns and

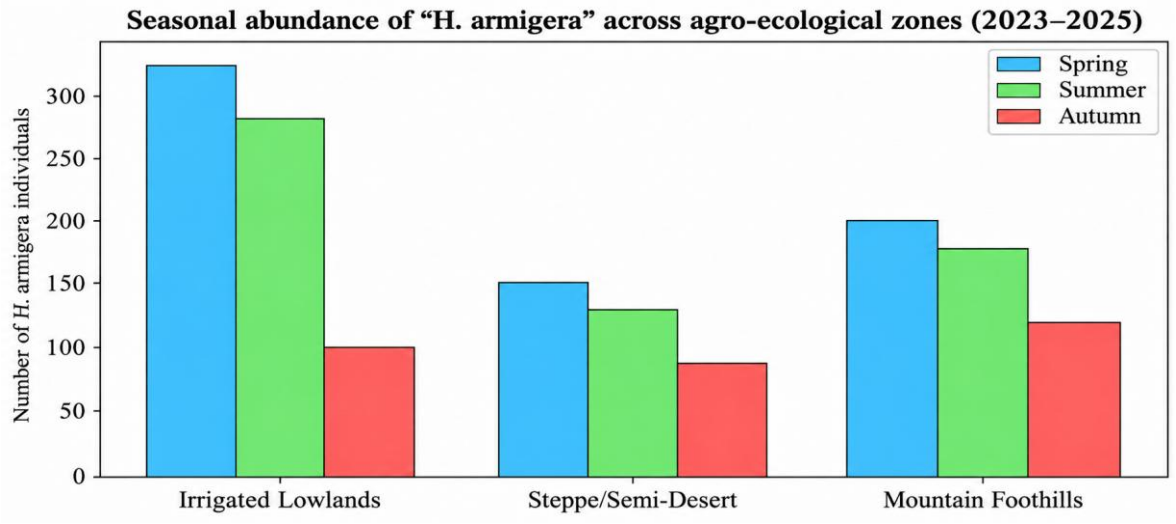


**Figure 1.** Seasonal dynamics of *Helicoverpa armigera* populations in major agroecological zones of Uzbekistan from 2023 to 2025.

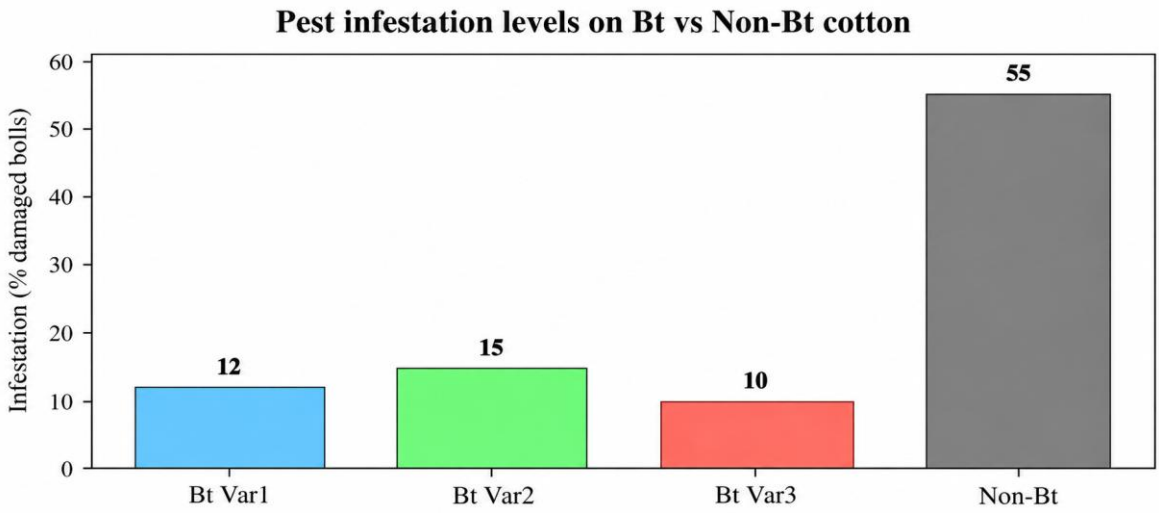


**Figure 2.** Infestation levels of *Helicoverpa armigera* on transgenic *Bt*-cotton varieties compared with non-*Bt* cotton in Uzbekistan field trials during 2023–2025.

climatic shifts directly influenced the pest ecology, species diversity, and host-plant utilization (Chen *et al*., 2021).

Seasonal pest population dynamics revealed that pest activity peaks coincided with main crop growth stages. With these temporal fluctuations, effective integrated pest management (IPM) programs can effectively optimize the intervention timing to reduce pesticide dependency (Omonov *et al*., 2023). Host-plant association highlighted the importance of crop selection and rotation; considerable correlation between pest density and host availability suggested that habitat manipulation, such as intercropping, could effectively suppress the outbreaks (Omonov *et al*., 2025).

Economic analysis confirmed that pest-induced yield losses pose significant challenges. The implementation of *Bt*-cotton

cultivars, biological control, and targeted IPM strategies could successfully mitigate these losses and enhance the sustainable crop production (Pedigo and Rice, 2015; Gurr *et al*., 2017; Pimentel, 2022). Moreover, the insecticide resistance management remains a crucial component, requiring adherence to established modes of action and sustainable agronomic practices (Sparks and Nauen, 2015). Integrating these biotechnological approaches with ecological engineering is essential for the long-term sustainability of the cotton sector (Sobirova *et al*., 2024). Overall, the promising study provided the baseline data on pest biodiversity and ecological dynamics, supporting the development of resilient agricultural policies in Uzbekistan.

One should note that the design of this study sought primarily to assess pest biodiversity, distribution patterns, and ecological dynamics rather than to compare experimentally the effectiveness of different pest management strategies. Therefore, the recommendations regarding IPM, intercropping, and biological control depended on the observed pest-host relationships, seasonal population trends, and findings reported in previous studies. Further field-based experiments are necessary to quantitatively evaluate and compare the efficacy of these management approaches under the agroecological conditions of Uzbekistan.

Although this study did not investigate insecticide resistance, previous research has documented resistance of *H. armigera* and *S. exigua* to pyrethroids, organophosphates, and other commonly used insecticides. Metabolic detoxification and target-site mutations have become the principal resistance mechanisms. Future monitoring programs are crucial to assess resistance status in Uzbekistan and improve resistance management strategies.

Finally, management of insecticide resistance remains critical. Tabashnik and Carrière (2017) reported that maintaining refuge areas is essential for the longevity of *Bt*-transgenic crops. Similarly, Sobirova *et al*. (2024) noted that minimizing broad-spectrum pesticide use was the key element of sustainable crop protection strategies.

## CONCLUSIONS

The study provided a comprehensive evaluation of the genetic resistance and entomological performance of transgenic *Bt*-cotton cultivars against *Helicoverpa armigera* under Uzbekistan's agroecological conditions. The results revealed significant spatial and temporal variations in pest pressure, with irrigated lowlands identified as high-risk zones, requiring tailored management interventions. By integrating genetic, ecological, and entomological perspectives, the timely research established a holistic understanding of crop-pest interactions that exceeds the scope of traditional chemical control studies. The generated baseline data on population dynamics and environmental correlations provide a crucial foundation for developing predictive models for sustainable pest management. Consequently, the implementation of integrated pest management (IPM) can effectively mitigate the economic losses in cotton and vegetable crops.

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