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ISSIQXONA VA OCHIQ MAYDONLARDAGI POMIDOR VA BULG'OR QALAMPIRI EKINLARINI TUTA ABSOLUTA ZARARKUNANDASIDAN HIMOYA QILISHNING SAMARALI USULLARI

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Annotatsiya. Ushbu sharh maqolada pomidor va bulg'or qalampiri ekinlarining eng xavfli zararkunandasi bo'lgan pomidor kuyasi (*Tuta absoluta* Meyrick) ga qarshi kurashning zamonaviy strategiyalari tahlil qilinadi. Maqolada zararkunandaning global tarqalishi, biologik adaptatsiyasi va so'nggi yillarda bulg'or qalampiriga beradigan zarari dunyo olimlarining tadqiqotlari asosida yoritilgan. Shuningdek, feromon tutqichlar, fizik kurash, biologik kurash (*Nesidiocoris tenuis*, *Trichogramma*) va kimyoviy vositalarning samaradorligi qiyosiy tahlil qilingan. Tadqiqot natijalari shuni ko'rsatadiki, faqat integrallashgan himoya tizimi (IPM) orqali zararkunandaning insektitsidlarga chidamliligini kamaytirish va hosildorlikni barqaror saqlash mumkin.

Kalit so'zlar: tuta absoluta, integrallashgan himoya (ipm), rezistentlik, feromon tuzoqlar, biologik nazorat, issiqxona, bulg'or qalampiri, hosildorlik.

Abstract. This review article analyzes modern management strategies against the South American tomato pinworm (*Tuta absoluta* Meyrick), the most formidable pest of tomato and bell pepper crops. Based on global research findings, the article highlights the pest's worldwide expansion, biological adaptation, and its recent host-shift dynamics toward bell peppers (*Capsicum annuum*). A comparative analysis of pheromone monitoring, physical barriers, biological agents (*Nesidiocoris tenuis*, *Trichogramma*), and selective chemical interventions is presented. Synthesis of the data suggests that only a robust Integrated Pest Management (IPM) framework can effectively mitigate insecticide resistance and ensure sustainable yield preservation in both greenhouse and open-field systems.



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Keywords: tuta absoluta, integrated pest management (ipm), resistance, pheromone traps, biological control, greenhouse, bell pepper, crop yield.

Аннотация. В данной обзорной статье анализируются современные стратегии борьбы с наиболее опасным вредителем пасленовых культур южноамериканской томатной молью (*Tuta absoluta* Meyrick). На основе анализа мировых исследований рассматриваются динамика глобального распространения вредителя, его биологическая адаптация и процесс перехода на сладкий перец (*Capsicum annuum*). Проведен сравнительный анализ эффективности феромонного мониторинга, физических барьеров, биологических агентов (*Nesidiocoris tenuis*, *Trichogramma*) и селективных инсектицидов. Сделан вывод, что только комплексная система интегрированной защиты растений (ИПМ) позволяет эффективно сдерживать резистентность вредителя и обеспечивать устойчивую урожайность.

Ключевые слова: tuta absoluta, интегрированная защита (ИПМ), резистентность, феромонные ловушки, биологический контроль, теплицы, сладкий перец, урожайность.

INTRODUCTION

The global agricultural landscape is currently facing unprecedented challenges due to climate change and the rapid intensification of international trade, which have facilitated the transboundary spread of highly invasive pests. Among these, the South American Tomato Pinworm, *Tuta absoluta* (Meyrick) (*Lepidoptera: Gelechiidae*), has emerged as the most formidable threat to the production of solanaceous crops worldwide. Primarily targeting tomatoes (*Solanum lycopersicum*), this pest has recently demonstrated an expanding host range, significantly impacting bell peppers (*Capsicum annuum*) in both greenhouse and open-field environments. The urgency of addressing this pest stems from its exceptional reproductive capacity, high adaptability, and its propensity to develop resistance to conventional chemical control measures. Global Spread and Economic ImplicationsOriginally endemic to South America, *Tuta absoluta* underwent a dramatic "biological invasion" following its first detection in Spain in 2006. In less than two decades, it has colonized the Mediterranean basin, Europe, North Africa, the Middle East, and Central Asia, including Uzbekistan. Currently, it is officially recorded in over 100 countries. Statistical data indicates that without rigorous management, *Tuta absoluta* can cause yield losses ranging from 80% to 100%. Globally, the annual economic impact is estimated to exceed \$500 million USD. In major exporting nations such as Italy, Greece, and Turkey, massive outbreaks have historically led to a 60-70% decline in marketable yield, threatening not only farmer livelihoods but also national export stability and food security. The Crisis in Greenhouse and Open-Field SystemsIn Uzbekistan, the strategic expansion of modern greenhouse complexes has inadvertently created an ideal ecological niche for this pest. The controlled microclimate of greenhouses-characterized by stable



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temperatures and high humidity-allows *Tuta absoluta* to bypass winter dormancy, potentially completing 10 to 12 generations per year. These facilities act as permanent "infection reservoirs," facilitating the mass migration of the pest to open-field crops during the spring and summer planting seasons. Furthermore, the vulnerability of bell peppers has become a critical focal point of recent entomological research. While tomatoes remain the primary host, *Tuta absoluta* has increasingly adapted to bell pepper crops. Larval mining within the leaves reduces the photosynthetic capacity by up to 40%, while the penetration of larvae into the fruit near the calyx renders the produce unmarketable and unfit for export. This shift poses a new, unforeseen economic burden on diversified vegetable growers. Ecological Concerns and Pesticide ResistanceThe urgency of this topic is further underscored by the failure of traditional chemical interventions. The indiscriminate and frequent application of broad-spectrum insecticides (often exceeding 15-20 applications per season) has led to the rapid development of genetic resistance in *Tuta absoluta* populations, particularly against pyrethroids and organophosphates. This chemical dependency not only increases production costs but also results in high pesticide residues in food, environmental degradation, and severe risks to human health.

Given this critical scenario, there is an urgent need to transition from purely chemical-based control to a robust Integrated Pest Management (IPM) framework. This article analyzes the most effective, economically viable, and ecologically sustainable methods for protecting tomato and bell pepper crops. It evaluates the efficacy of digital monitoring systems, pheromone-based mass trapping, and the strategic use of new-generation selective insecticides. By synthesizing international best practices with localized data from Uzbekistan's climatic zones, this study aims to provide a comprehensive roadmap for mitigating the impact of this devastating pest.

MATERIALS AND METHODS

The methodology of this systematic review is centered on a comprehensive and critical analysis of existing scientific literature and technical data concerning the management of *Tuta absoluta* in tomato and bell pepper crops. To ensure the reliability of the synthesized information, a multi-stage data retrieval process was initiated using global academic repositories such as Web of Science, Scopus, and the CABI Invasive Species Compendium, covering the significant research period from the pest's initial European invasion in 2006 through 2024. The selection process was governed by strict inclusion criteria, focusing on peer-reviewed studies that provide quantitative data on integrated pest management (IPM) efficacy, insecticide resistance ratios, and the biological performance of predatory insects in both controlled greenhouse environments and diverse open-field ecosystems. Specific attention was directed toward research evaluating the host-shift dynamics of the pest to *Capsicum annuum*, ensuring the review addresses the evolving threat to bell pepper production. The gathered data were categorized and cross-referenced to



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identify correlations between different control strategies, such as the synergy between physical barriers like insect-proof netting and the subsequent success rate of biological agents. Furthermore, the effectiveness of various insecticide groups was assessed through a comparative analysis of their biological efficiency percentages as reported in international field trials. By synthesizing these diverse datasets, the methodology aims to provide a robust, evidence-based framework that adapts global best practices to the specific agro-climatic conditions of Central Asia, particularly focusing on the structural nuances of the expanding greenhouse sector in Uzbekistan.

RESULTS AND DISCUSSION

The analytical synthesis of global research findings indicates that the management of *Tuta absoluta* has undergone a significant paradigm shift from intensive chemical reliance to a multi-dimensional ecological approach. A primary result identified in the literature is the undeniable efficacy of pheromone-based monitoring systems. According to the data synthesized from Vacas et al. (2011), the implementation of mating disruption and mass trapping technologies can reduce fruit infestation in tomatoes by up to 75%, providing a robust alternative to early-season insecticide applications.

Table 1.

Comparative Efficacy Analysis of Control Strategies Against *Tuta absoluta*

This table synthesizes the effectiveness of various Integrated Pest Management (IPM) components based on international research.

No	Control Strategy	Specific Tools / Agents	Efficacy Rate (%)	Key Advantages and Characteristics	Primary Source
1.	Biological Control	<i>Nesidiocoris tenuis</i> (Mirid bug)	77% - 97%	Targets eggs and young larvae; establishes long-term presence in the crop.	Arno et al. (2009)
2.	Biological Control	<i>Trichogramma pretiosum</i> (Egg parasitoid)	70% - 85%	Neutralizes the pest at the egg stage; prevents larval emergence.	Chailleux et al. (2013)
3.	Biotechnological	Sex Pheromones (Mass trapping)	52% - 75%	Disrupts the mating cycle and monitors adult male population density.	Vacas et al. (2011)
4.	Physical-Mechanical	50-mesh Anti-insect Netting	65% - 90%	Mechanically excludes adults; reduces insecticide application by up to 50%.	Khasanov & Sulaymonov (2020)



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5.	Chemical	Chlorantraniliprole (Diamide)	85% - 95%	High mortality rate; strong translaminar activity within leaf tissues.	Desneux et al. (2021)
6.	Chemical	Spinetoram (Spinosyn)	88% - 94%	Rapid "knockdown" effect; effective against all larval instars.	Bastola et al. (2020)

Furthermore, the discussion regarding host-shift dynamics, specifically the pest's adaptation to bell peppers (*Capsicum annuum*), reveals a critical ecological trend. While Biondi et al. (2018) observed that larval development on peppers is slightly less efficient than on tomatoes, the practical results in greenhouse settings suggest that peppers can still suffer significant commercial damage, with yield losses reaching 40% if left unmanaged. This host adaptation necessitates a revised monitoring protocol that includes all solanaceous crops within a single production unit. The performance of biological control agents serves as another focal point of current scientific discussion. The extensive field trials conducted by Arno et al. (2009) and further supported by regional observations from Khasanov and Sulaymonov (2020) demonstrate that predatory mirids like *Nesidiocoris tenuis* provide a "living barrier" against the pest.

Table 2.

Host-Shift Dynamics and Insecticide Resistance Profiles of *Tuta absoluta*

This table illustrates the comparative impact on different crops and the growing challenge of chemical resistance.

№	Parameter Type	Tomato (<i>S. lycopersicum</i>)	Bell Pepper (<i>C. annuum</i>)	Scientific Synthesis and Analysis	Key Researcher(s)
1.	Yield Loss (Unmanaged)	80% - 100%	25% - 40%	Tomato is the primary host; peppers serve as an adaptive secondary host.	Desneux et al. (2010); Biondi et al. (2018)
2.	Larval Survival Rate	High (95-100%)	Moderate (75-80%)	Development is slower on peppers, but fruit marketability is severely impacted.	Biondi et al. (2018)
3.	Resistance (Pyrethroids)	Extreme (High)	Extreme (High)	Documented resistance ratios exceeding 50-100 fold in many regions.	Zappala et al. (2013); Guedes et al. (2019)



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4.	Pesticide Application Frequency	15-20 times/season	8-12 times/season	High resistance forces growers to increase dosages, leading to chemical residue risks.	Guedes et al. (2019)
5.	Recommended Strategy	Robust IPM	Adaptive IPM	Reliance on single-mode-of-action chemicals accelerates genotype resistance.	Desneux et al. (2021)

The results show that maintaining a predator-to-prey ratio of 1:10 can suppress egg populations by over 80% without any supplementary chemical aid. However, the discussion also highlights a complex challenge: the rising trend of insecticide resistance. The findings of Zappala et al. (2013) and Guedes et al. (2019) provide sobering evidence of metabolic resistance to diamides and organophosphates. This data underscores that the biological efficiency (BE%) of even the most advanced chemicals, such as Chlorantraniliprole, is highly dependent on strict rotation schedules. Moreover, the integration of physical barriers has emerged as one of the most cost-effective and sustainable results in the reviewed literature. Comparison of production cycles shows that greenhouses utilizing 50-mesh anti-insect netting require approximately 50-60% fewer chemical treatments than standard facilities. The synergy between these physical exclusions and the strategic release of *Trichogramma* parasitoids has been identified as the most resilient model for Central Asian climates. In conclusion, the discussion illustrates that while *Tuta absoluta* remains a formidable threat, the transition toward a "bio-fix" guided Integrated Pest Management (IPM) framework combining pheromones, biological predation, and selective chemical rotation offers a sustainable pathway for protecting both tomato and bell pepper yields while ensuring the ecological safety of the agricultural environment.

CONCLUSION

In conclusion, the management of *Tuta absoluta* in tomato and bell pepper production has evolved from a crisis-response challenge into a complex scientific discipline requiring a multidisciplinary approach. The evidence synthesized in this review confirms that relying solely on chemical interventions is no longer a viable strategy due to the rapid development of insecticide resistance and the pest's high ecological adaptability. Instead, the most successful models for both greenhouse and open-field systems are built upon the foundation of Integrated Pest Management (IPM). The integration of physical barriers, such as 50-mesh netting, and the early establishment of biological control agents like *Nesidiocoris tenuis* and *Trichogramma species*, have proven to be the most sustainable methods for



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maintaining pest populations below economic injury levels. Furthermore, the role of sex pheromones has transitioned from a mere monitoring tool to a critical decision-support system that prevents unnecessary chemical applications. For regions such as Uzbekistan, adopting these integrated protocols is essential to ensure the long-term viability of the agricultural sector, protect the environment, and maintain the export quality of solanaceous crops. Ultimately, proactive monitoring and the strict rotation of selective insecticides remain the primary safeguards against the evolving threat of the South American tomato pinworm.

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