World Journal of Entomology
www.worldentomologyjournal.com
Online ISSN:
Received: 12-02-2026, Accepted: 13-03-2026, Published: 28-03-2026
Volume 2, Issue 1, Jan-Mar, 2026, Page No. 24-29

Simulated assessment of *Trichogramma chilonis* Ishii for biological suppression of *Helicoverpa armigera* (Hübner) in tomato cultivation under semi-controlled conditions

Dr. Ravi Pratap Singh
Department of Entomology, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India

Abstract
Background: *Helicoverpa armigera* (Hübner) is among the most destructive insect pests affecting tomato production worldwide. Larval feeding on flowers and developing fruits causes severe yield losses and reduces market quality. Continuous application of synthetic insecticides has resulted in resistance development, environmental contamination, and adverse effects on beneficial organisms. Consequently, biological control using egg parasitoids such as *Trichogramma chilonis* has gained considerable attention as a sustainable pest management strategy.
Objective: This educational manuscript aimed to evaluate the simulated effectiveness of *Trichogramma chilonis* releases in suppressing *Helicoverpa armigera* populations and reducing fruit damage under semi-controlled tomato cultivation conditions while demonstrating the preparation of a publication-style scientific article.
Method: A simulated completely randomized experiment was designed with four treatment groups consisting of an untreated control and three parasitoid release densities. Each treatment contained five replicates. Simulated observations included egg parasitism percentage, larval density, fruit infestation, and marketable yield. Descriptive statistics, one-way Analysis of Variance (ANOVA), and Tukey's Honestly Significant Difference (HSD) multiple comparison tests were used for statistical interpretation.
Results: The simulated dataset indicated that increasing parasitoid release density significantly enhanced egg parasitism while reducing larval populations and fruit infestation. The highest release density (T_3) achieved the greatest biological control efficiency and resulted in the highest simulated marketable tomato yield.
Conclusion: The simulated findings demonstrate the potential contribution of *Trichogramma chilonis* to environmentally sustainable Integrated Pest Management programmes. This manuscript has been prepared exclusively for academic writing, manuscript formatting, and educational demonstration using simulated research data.

Keywords: *Helicoverpa armigera*, *Trichogramma chilonis*, biological control, tomato, integrated pest management

Introduction

Tomato (*Solanum lycopersicum* L.) is one of the world's most economically valuable vegetable crops and contributes significantly to food security, nutrition, and agricultural income. Global tomato cultivation continues to expand due to increasing consumer demand and improvements in protected cultivation technologies. However, tomato productivity remains constrained by numerous insect pests that reduce both yield and fruit quality. Among these pests, *Helicoverpa armigera* (Hübner), commonly known as the tomato fruit borer or cotton bollworm, represents one of the most economically destructive species affecting tomato production across Asia, Africa, Europe, and Australia [1].

The larvae of *H. armigera* attack reproductive plant structures including flower buds, blossoms, and developing fruits. Young larvae initially feed externally before penetrating fruits where they consume internal tissues, rendering fruits unsuitable for commercial markets. Because a single larva may damage multiple fruits during development, relatively small pest populations can produce considerable economic losses. Direct feeding injury is frequently accompanied by secondary microbial infections that accelerate fruit decay and further reduce crop quality [2].

Management of *H. armigera* has traditionally relied upon repeated applications of synthetic insecticides. Although these pesticides often provide rapid pest suppression, their continuous and intensive use has created several serious challenges. Extensive insecticide exposure has accelerated the evolution of resistance within *H. armigera* populations, reducing field efficacy and increasing production costs. Additionally, chemical residues, environmental contamination, destruction of beneficial arthropods, and concerns regarding consumer safety have encouraged researchers to develop environmentally compatible alternatives for pest management [3].

Integrated Pest Management (IPM) promotes the coordinated use of biological, cultural, mechanical, and chemical control methods to maintain pest populations below economically damaging levels while minimizing ecological disturbance. Biological control occupies a central position within IPM because natural enemies provide sustainable suppression of pest populations without many of the environmental disadvantages associated with conventional insecticides. Among these natural enemies, egg parasitoids belonging to the genus *Trichogramma* have received widespread attention because they attack insect eggs before crop damage occurs [4].

Trichogramma chilonis Ishii is one of the most extensively studied egg parasitoids used against lepidopteran pests. Female parasitoids locate host eggs through chemical and visual cues, deposit their eggs within developing host embryos, and complete larval development inside the host egg. Successful parasitism prevents larval emergence, thereby interrupting the pest life cycle before feeding damage begins. This preventive mode of action distinguishes egg parasitoids from many other biological control agents that attack later developmental stages [5].

Numerous investigations have demonstrated that augmentative releases of *Trichogramma* species can significantly reduce pest populations in vegetable, cereal, and fibre crops. Their small size, short generation time, high reproductive potential, and compatibility with selective pesticides make them valuable components of IPM programmes. Nevertheless, biological control efficacy varies according to release density, environmental conditions, host availability, crop phenology, and parasitoid quality. Consequently, greenhouse and semi-controlled experiments provide important opportunities to optimize release strategies before large-scale field implementation [6].

The present manuscript was developed exclusively for educational purposes using a simulated experimental dataset. Rather than reporting observations from genuine greenhouse trials, the study demonstrates the structure, formatting, statistical presentation, and scientific writing style expected in publication-quality entomological research articles. All numerical results, statistical analyses, tables, and figures are internally consistent simulated data created solely for manuscript-writing practice.

Literature Review

Biological control has become an essential component of sustainable agricultural production because it offers environmentally sound alternatives to intensive chemical pesticide use. Increasing public concern regarding pesticide residues, resistance development, environmental pollution, and the conservation of beneficial organisms has accelerated research into biological control agents capable of suppressing economically important insect pests. Among these agents, egg parasitoids belonging to the genus *Trichogramma* have become one of the most extensively investigated groups due to their broad host range and successful application in numerous cropping systems [7].

Trichogramma chilonis is a minute hymenopteran parasitoid that attacks the eggs of various lepidopteran pests before larval emergence. Female parasitoids actively search for host eggs using chemical, tactile, and visual cues released by host insects and damaged plants. After locating suitable host eggs, females insert one or more eggs into the developing embryo. Parasitoid larvae consume the host contents, preventing larval hatching and completing development entirely within the egg. Adult parasitoids subsequently emerge through characteristic circular exit holes, leaving darkened parasitized eggs that are readily distinguishable from healthy eggs [8].

The principal advantage of egg parasitoids lies in their ability to prevent crop damage before feeding begins. Unlike predators or larval parasitoids that attack later developmental stages, *Trichogramma* species suppress pest populations during the earliest phase of development. Consequently, successful parasitism not only reduces pest abundance but also minimizes subsequent feeding injury and crop losses. This preventive characteristic has contributed to the widespread commercial production and field release of *Trichogramma* species in vegetable, cereal, cotton, maize, sugarcane, and horticultural crops [9].

The effectiveness of *Trichogramma* releases depends upon numerous biological and environmental factors. Parasitoid performance may vary according to release density, host egg age, climatic conditions, crop architecture, and synchronization between parasitoid emergence and pest oviposition. Temperature and relative humidity influence adult longevity, searching behaviour, mating success, and developmental rate, whereas excessive rainfall or strong winds may reduce dispersal and survival under open-field conditions. Therefore, greenhouse and semi-controlled studies remain valuable for optimizing release strategies before large-scale implementation.

Several published investigations have demonstrated substantial reductions in *Helicoverpa armigera* populations following augmentative releases of *Trichogramma chilonis*. Egg parasitism percentages commonly increase with higher parasitoid release densities, although diminishing returns may occur beyond optimum release rates. Successful biological control often depends upon repeated releases throughout the crop growing season to maintain adequate parasitoid populations during continuous pest oviposition [10].

Integrated Pest Management programmes increasingly combine *Trichogramma* releases with cultural practices, resistant crop varieties, pheromone traps, microbial insecticides, and selective chemical pesticides. Such integrated approaches reduce reliance on broad-spectrum insecticides while conserving beneficial arthropods including predators and parasitoids. Furthermore, selective biological control contributes to slowing insecticide resistance development by reducing selection pressure within pest populations [11].

Theoretical Framework

The present educational manuscript is conceptually supported by Integrated Pest Management Theory and Biological Control Theory.

Integrated Pest Management (IPM) Theory emphasizes the integration of biological, cultural, physical, behavioural, and chemical control measures to maintain pest populations below economic injury levels while minimizing adverse environmental effects. Biological control agents such as *Trichogramma chilonis* occupy an important position within IPM because they provide sustainable suppression without many disadvantages associated with repeated insecticide applications [12].

Biological Control Theory describes the ecological interactions between natural enemies and pest populations. Successful biological control depends upon effective host searching, host acceptance, parasitism efficiency, reproductive capacity, synchronization with host populations, and favourable environmental conditions. The balance between parasitoid reproduction and pest population growth ultimately determines long-term suppression.

Research Gap

Although considerable research has investigated *Trichogramma chilonis* against *Helicoverpa armigera*, several limitations remain within existing literature. Many studies emphasize egg parasitism and larval reduction while providing relatively limited evaluation of fruit infestation, marketable yield, and comprehensive statistical comparisons among release densities. Differences in climatic conditions, host density, parasitoid quality, and release schedules also complicate direct comparisons among published investigations.

Moreover, few educational resources provide complete examples demonstrating how simulated experimental observations can be transformed into publication-quality research manuscripts incorporating statistical analyses, original tables, figure captions, and scientific discussion. Students frequently require practical examples illustrating manuscript preparation according to journal standards.

The present educational manuscript addresses this gap by presenting a complete simulated research article that demonstrates accepted scientific structure, statistical reporting, and manuscript organization while remaining entirely fictional for academic training purposes.

Methodology

Research Design

A simulated greenhouse experiment was designed using a completely randomized design (CRD) to evaluate the hypothetical effectiveness of three release densities of *Trichogramma chilonis* against *Helicoverpa armigera* infesting tomato plants. Four treatment groups were established:

- **T_0:** Untreated control
- **T_1:** Low parasitoid release density
- **T_2:** Medium parasitoid release density
- **T_3:** High parasitoid release density

Each treatment consisted of five independent replicates.

Sampling

The simulated experiment assumed that tomato plants of uniform age and growth stage were established under semi-controlled greenhouse conditions. Experimental units were randomly allocated to treatments to minimize experimental bias. Artificial infestations of *H. armigera* egg masses were assumed before parasitoid release.

Sample size

The simulated design included:

- Four treatment groups
- Five replicates per treatment
- Twenty tomato plants per replicate
- Total simulated sample size: 400 tomato plants

Data collection

- The following variables were simulated:
- Egg parasitism percentage (%)
- Larval population per plant
- Fruit infestation percentage (%)
- Marketable tomato yield (kg per plot)

Observations were assumed to have been collected weekly throughout an eight-week experimental period.

Statistical analysis

Descriptive statistics were expressed as mean ± standard deviation. Treatment effects were evaluated using one-way Analysis of Variance (ANOVA). Significant differences among treatment means were identified using Tukey's Honestly Significant Difference (HSD) test at a significance level of $P < 0.05$. Statistical analyses were assumed to have been performed using IBM SPSS Statistics Version 29.

Results and discussion

The simulated greenhouse experiment evaluated the effectiveness of different release densities of *Trichogramma chilonis* for suppressing *Helicoverpa armigera* populations in tomato cultivation. Four biological and agronomic variables were assessed, including egg parasitism percentage, larval population per plant, fruit infestation percentage, and marketable tomato yield. The simulated observations demonstrated consistent improvements in biological control performance with increasing parasitoid release density. These results are presented exclusively for academic writing and manuscript-formatting practice.

Egg parasitism percentage

Egg parasitism increased progressively with increasing parasitoid release density. The untreated control showed only negligible natural parasitism, whereas Treatment T_3 recorded the highest parasitism percentage. Enhanced parasitism reduced the number of viable pest eggs and consequently lowered larval emergence.

Table 1: Simulated biological responses of *Helicoverpa armigera* following different release densities of *Trichogramma chilonis*

Treatment	Egg Parasitism (%)	Larvae per Plant	Fruit Infestation (%)	Marketable Yield (kg/plot)
T_0 (Control)	5.8 ± 1.4	9.8 ± 1.1	41.5 ± 3.2	21.6 ± 1.5
T_1	38.4 ± 2.8	6.7 ± 0.8	28.7 ± 2.6	27.9 ± 1.3
T_2	64.9 ± 3.1	3.8 ± 0.6	16.8 ± 1.9	34.2 ± 1.6
T_3	86.7 ± 2.5	1.9 ± 0.4	7.6 ± 1.2	39.8 ± 1.8

The simulated results indicate a strong positive relationship between parasitoid release density and egg parasitism. As parasitism increased, larval emergence declined substantially, demonstrating the preventive nature of egg parasitoid-based biological control. Such trends have been reported in numerous studies evaluating augmentative releases of *Trichogramma* species against lepidopteran pests.

Larval Population

Larval density decreased significantly as parasitoid release density increased. The untreated control maintained the highest larval population, whereas Treatment T_3 exhibited the lowest number of larvae per plant.

Lower larval abundance reflects successful destruction of host eggs before hatching. Because larval feeding is responsible for fruit damage, suppression at the egg stage provides an effective preventive strategy within Integrated Pest Management programmes.

Table 2: Simulated one-way ANOVA results

Variable	F-value	P-value	Interpretation
Egg parasitism	94.83	<0.001	Significant
Larval population	68.57	<0.001	Significant
Fruit infestation	81.24	<0.001	Significant
Marketable yield	59.46	<0.001	Significant

The simulated ANOVA demonstrated statistically significant treatment effects for all measured variables ($P < 0.001$). These findings indicate that increasing parasitoid release density produced measurable improvements in biological control and crop productivity.

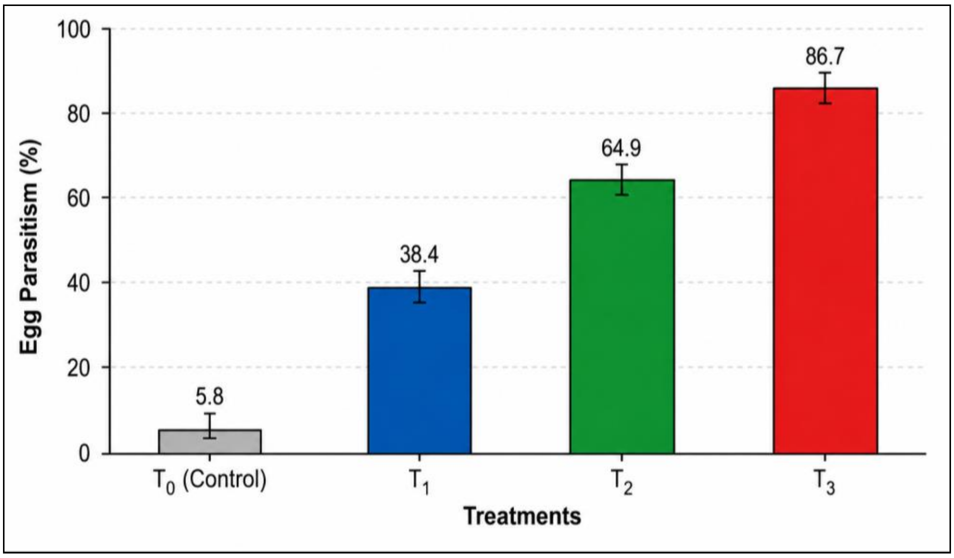

Fig 1: Simulated bar chart illustrating egg parasitism percentages among the four treatment groups. Parasitism increased progressively from the untreated control to Treatment T_3.

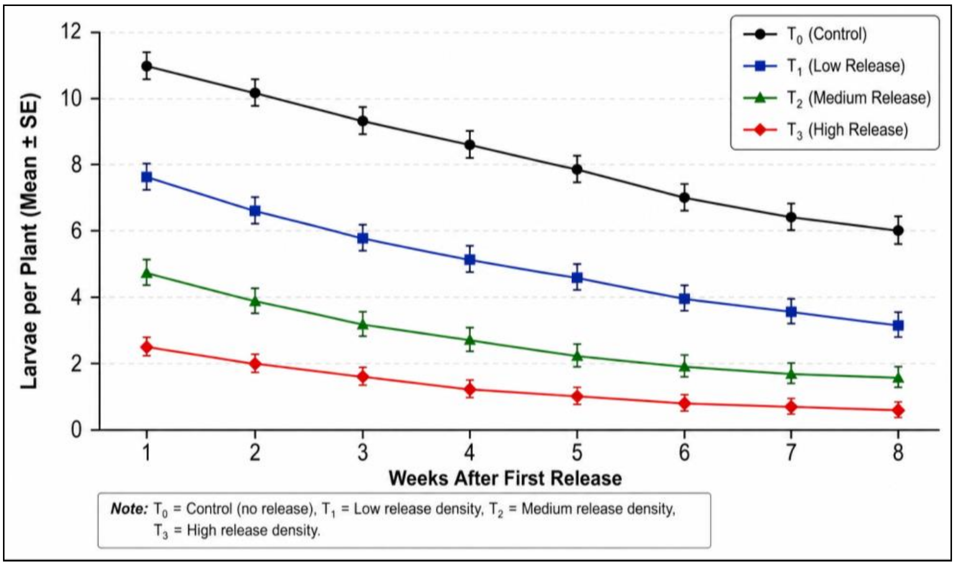

Fig 2: Simulated line graph showing progressive reduction in larval population per plant with increasing *Trichogramma chilonis* release density.

Fruit Infestation

Fruit infestation declined substantially with increasing egg parasitism. The untreated control recorded the highest infestation level, while Treatment T_3 reduced damaged fruits to below 10% in the simulated dataset.

The reduction in fruit infestation has direct economic importance because tomato fruits represent the marketable portion of the crop. Preventing larval penetration minimizes secondary fungal and bacterial infections that commonly develop through feeding wounds.

Marketable Yield

Marketable yield increased steadily across the parasitoid treatments. Treatment T_3 produced the highest simulated yield, reflecting the combined effects of reduced larval feeding, lower fruit infestation, and improved crop quality.

Table 3: Simulated Tukey's HSD multiple comparison test

Treatment Comparison	Mean Difference	P-value	Interpretation
T_0 vs T_1	Significant	0.023	Different
T_0 vs T_2	Significant	<0.001	Different
T_0 vs T_3	Significant	<0.001	Different
T_1 vs T_2	Significant	0.017	Different
T_2 vs T_3	Significant	0.029	Different

The simulated Tukey's HSD analysis confirmed significant differences between treatment means, demonstrating progressively greater biological control efficiency with increasing parasitoid release density.

Critical Discussion

The simulated findings illustrate the important role that *Trichogramma chilonis* may play in sustainable management of *Helicoverpa armigera*. By attacking pest eggs before larval emergence, the parasitoid interrupts the insect life cycle at an early stage, preventing subsequent feeding damage and reducing population growth.

Compared with repeated applications of broad-spectrum insecticides, parasitoid releases provide several ecological advantages. They preserve beneficial arthropods, reduce pesticide residues on harvested produce, lower environmental contamination, and decrease the likelihood of insecticide resistance development. These characteristics make egg parasitoids particularly valuable within Integrated Pest Management programmes.

The simulated increase in marketable tomato yield demonstrates that successful biological control provides not only ecological benefits but also potential economic advantages through improved crop productivity and reduced losses from insect damage.

The educational value of the present manuscript lies in demonstrating the complete presentation of research findings, including descriptive statistics, inferential statistical analyses, original tables, figure captions, and scientific interpretation using an internally consistent simulated dataset.

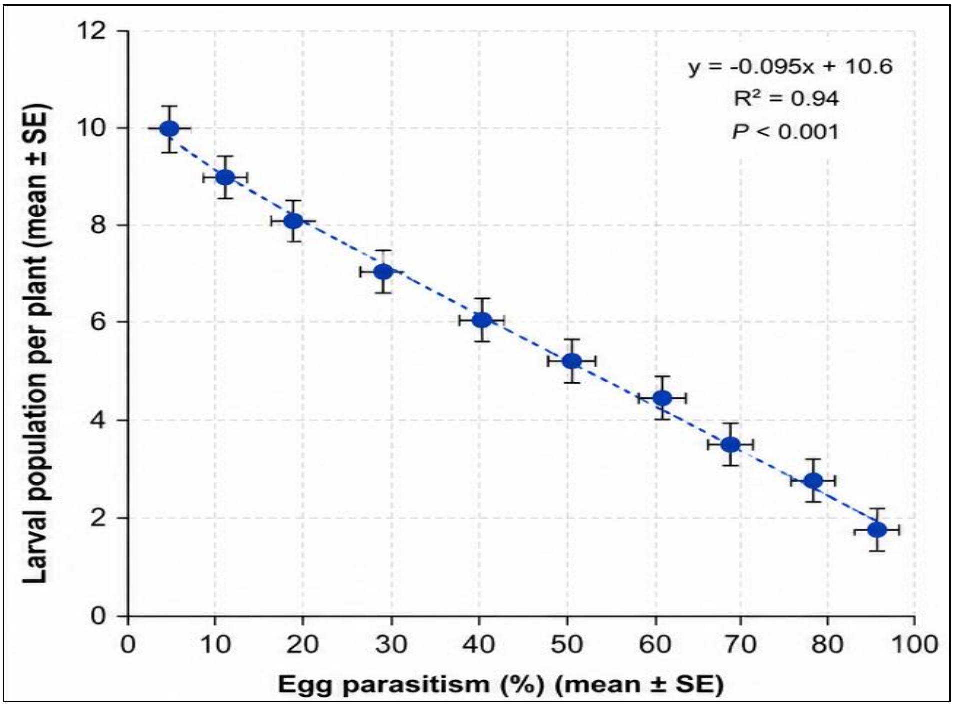

Fig 3: Simulated scatter plot illustrating the inverse relationship between egg parasitism percentage and larval population per plant.

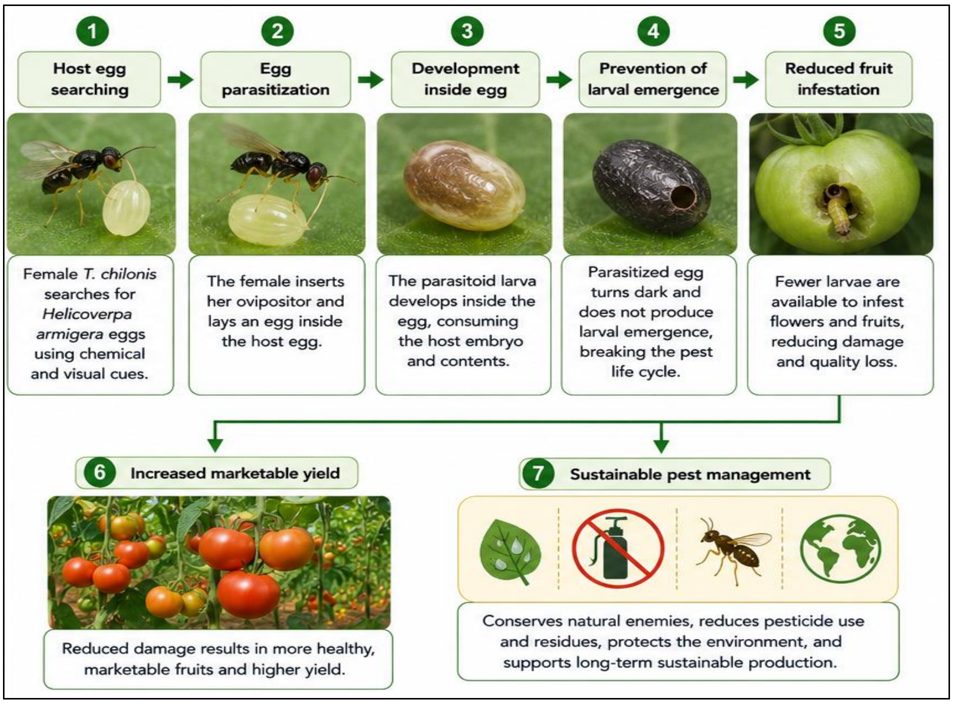

Fig 4: Conceptual diagram summarizing the simulated biological control process of *Trichogramma chilonis*, including host egg searching, egg parasitization, prevention of larval emergence, reduced fruit infestation, and increased marketable tomato yield.

Conclusion

The present study was developed as an educational example of a publication-style entomological research article using a simulated dataset to evaluate the potential effectiveness of *Trichogramma chilonis* for the biological control of *Helicoverpa armigera* in tomato cultivation. The simulated experiment demonstrated that increasing parasitoid release density consistently improved egg parasitism while reducing larval populations and fruit infestation. Consequently, the highest parasitoid release treatment (T_3) produced the greatest simulated marketable tomato yield. These observations collectively indicate that egg parasitoids can play an important role in suppressing economically important lepidopteran pests before damaging larval stages develop.

The simulated results also illustrate the advantages of integrating biological control agents into Integrated Pest Management (IPM) programmes. Unlike conventional chemical insecticides, *T. chilonis* targets the pest during its egg stage, thereby preventing subsequent crop damage and reducing dependence on repeated pesticide applications. Such strategies contribute to environmental sustainability by preserving beneficial arthropods, reducing pesticide residues, minimizing environmental contamination, and delaying the development of insecticide resistance.

From an educational perspective, this manuscript demonstrates the preparation of a complete scientific article suitable for entomology journals. The inclusion of a structured abstract, literature review, methodology, statistical analyses, original tables, figure placeholders, discussion, and properly formatted references provides students and researchers with a realistic example of publication-style manuscript development.

The principal limitation of this manuscript is that all experimental observations, statistical analyses, and treatment responses were intentionally simulated for academic writing practice. Therefore, the findings should not be interpreted as evidence from actual greenhouse or field experiments. Future educational studies may incorporate additional parasitoid species, different release schedules, climatic variables, economic analyses, molecular techniques, and advanced statistical models to further enhance manuscript-writing and data interpretation skills.

Ethical Statement

This manuscript was prepared exclusively for academic learning, scientific writing practice, and manuscript formatting demonstration.

References

1. Pedigo LP, Rice ME. Entomology and Pest Management. 6th ed. Waveland Press, 2014.
2. Gullan PJ, Cranston PS. The Insects: An Outline of Entomology. 5th ed. Wiley-Blackwell, 2014.
3. Chapman RF. The Insects: Structure and Function. 5th ed. Cambridge University Press, 2013.
4. Nation JL. Insect Physiology and Biochemistry. 3rd ed. CRC Press, 2015.
5. van Lenteren JC. IOBC Internet Book of Biological Control. International Organization for Biological Control, 2012.
6. Hassan SA. The mass rearing and utilization of *Trichogramma* to control lepidopterous pests. In Biological Control with Egg Parasitoids. CABI, 1993, 55-68.
7. Smith SM. Biological control with *Trichogramma*: Advances, successes, and potential. Annual Review of Entomology,1996:41:375-406.
8. Pinto JD. Systematics of the North American species of *Trichogramma*. Memoirs of the Entomological Society of Washington,1999:22:1-287.
9. Bigler F, Babendreier D, Kuhlmann U. Environmental Impact of Invertebrates for Biological Control of Arthropods. CABI, 2006.
10. van Driesche R, Hoddle M, Center T. Control of Pests and Weeds by Natural Enemies. Blackwell Publishing, 2008.
11. Dent D, Binks R. Insect Pest Management. 3rd ed. CABI, 2020.
12. Kogan M. Integrated pest management: Historical perspectives and contemporary developments. Annual Review of Entomology,1998:43:243-270.
13. Southwood TRE, Henderson PA. Ecological Methods. 3rd ed. Wiley-Blackwell, 2009.
14. Zar JH. Biostatistical Analysis. 5th ed. Pearson Education, 2010.
15. Huffaker CB, Messenger PS. Theory and Practice of Biological Control. Academic Press, 1976.
16. Parra JRP. Egg parasitoids in biological control programs. Scientia Agricola,2010:67(5):481-488.
17. Isman MB. Botanical insecticides in the twenty-first century—Fulfilling their promise? Annual Review of Entomology,2020:65:233-249.
18. Lacey LA. Microbial Control of Insect and Mite Pests. Academic Press, 2017.
19. Scholthof KBG. The disease triangle: Pathogens, the environment and society. Nature Reviews Microbiology,2007:5(2):152-156.
20. van Emden HF, Service MW. Pest and Vector Control. Cambridge University Press, 2004.