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Research Article

Host Preference of *Helicoverpa armigera* Hübner Assessed through Antixenosis Tests in Selected Tomato Varieties

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ABSTRACT

The oviposition preference of *Helicoverpa armigera* on six tomato varieties (Red King, Rio Grande, Florida King, Roma, Sahel, and 1359) was evaluated through free-choice and no-choice tests at Tarnab Farm, Peshawar, Pakistan, to identify extremes for potential IPM integration. In free-choice tests, Rio Grande received significantly ($P < 0.05$) more eggs (mean 324.5; ROP 24.8) than all other varieties, followed by Roma (309.6; ROP 23.7) and Florida King (265.4; ROP 20.3). Red King (194.3; ROP 14.8) and 1359 (201.7; ROP 15.4) were less preferred, while Sahel (150.9; ROP 11.5) was least preferred. No-choice tests confirmed Rio Grande as most preferred (325.4; ROP 24.9) and Sahel as least preferred (160.3; ROP 12.1), with Roma consistently ranked second (310.1; ROP 23.8). Electrical Penetration Graph (EPG) analysis under whole-plant conditions revealed significant ($P < 0.05$) differences among varieties in number of probes, total probing duration, and pathway phase parameters. Rio Grande recorded the highest values, followed by Florida King and Roma; Red King and Sahel exhibited the lowest, indicating reduced feeding activity. Under detached-leaf conditions, no significant differences were observed, suggesting uniform feeding behaviour in the absence of whole-plant cues. On the whole, oviposition and feeding behaviour of *H. armigera* were strongly influenced by varietal characteristics. Sahel, Red King, and 1359 were identified as less susceptible, making them promising for pest-resistant cropping systems. Incorporating such varieties into IPM programs can reduce *H. armigera* impact and reliance on chemical control.

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Introduction

Helicoverpa armigera (Hübner), commonly known as the cotton bollworm or tomato fruit borer, is a highly polyphagous pest affecting more than 180 plant species, including several economically important crops such as tomato (*Solanum lycopersicum*) (Kumar et al., 2023). In tomato cultivation, *H. armigera* larvae cause significant damage by feeding on leaves, flowers, and fruits, resulting in yield and quality losses that can exceed 70% under high infestation levels (Terlemezyan et al., 2025). The pest's widespread resistance to conventional chemical insecticides (Liang et al., 2025) has further complicated management efforts, highlighting the urgent need for alternative, sustainable control strategies.

One promising approach is host plant resistance, particularly through antixenosis, a mechanism that reduces pest attraction and suitability for oviposition, thereby limiting pest population establishment (Chavan, 2025). Antixenosis affects pest behavior through factors such as plant morphology, surface chemistry, and the presence of glandular trichomes, which deter egg-laying on less favorable cultivars (Shivannanavara et al., 2025). Incorporating naturally pest-deterrent traits into tomato cultivars provides a sustainable and environmentally friendly strategy, aligning well with integrated pest management (IPM) programs aimed at minimizing chemical inputs and ecological risks (Painter, 1951; Panda and Khush, 1995).

Moreover, integrating host plant resistance with biological control agents has shown promising results in managing *H. armigera* infestations. For example, natural enemies such as *Trichogramma* spp. and *Chrysoperla carnea* can complement antixenosis traits by targeting various life stages of the pest, enhancing overall suppression (Badenes-Pérez, 2025). Studies have demonstrated that such combined approaches can effectively reduce *H. armigera* populations over time (Liang et al., 2025), offering a more holistic and sustainable pest management solution.

Previous research has explored *H. armigera*'s ovipositional preferences on different tomato cultivars, identifying specific varietal traits, such as leaf pubescence, biochemical profiles, and plant volatiles that influence pest behavior. For instance, glandular trichomes on tomato leaves may secrete acyl sugars and other compounds that interfere with *H. armigera*'s feeding and reproductive activities (Usman et al., 2013). However, much of the existing literature has been limited to trials involving only one or two varieties and often lacks a standardized comparative framework across a broader range of commercially relevant cultivars (Thakur et al., 2018). This gap limits the potential for developing more resilient tomato genotypes through breeding.

To address this knowledge gap, the present study conducted a controlled multi-choice oviposition trial to assess *H. armigera*'s preferences across six commercially important tomato cultivars, Red King, Rio Grande, Florida King, Roma, Sahel, and 1359. These varieties were selected based on their agronomic relevance and preliminary observations suggesting potential resistance traits. This systematic evaluation aims to identify specific antixenosis characteristics that could inform future breeding programs (Ali et al., 2019). Unlike earlier studies, this research employs a broader varietal comparison under uniform conditions, enabling the identification of standout resistance traits. The findings are expected to offer valuable understandings for plant breeders and IPM practitioners, contributing to the development of pest-resistant tomato varieties that support sustainable agricultural practices (Smith and Clement, 2012).

Materials and Methods

Experimental design and insect rearing

The study was conducted during the summer of 2021 at the Entomology Laboratory, Tarnab Farm, Peshawar, to evaluate the ovipositional antixenosis of *Helicoverpa armigera* on six tomato (*Solanum lycopersicum*) varieties: Red King, Rio Grande, Florida King, Roma, Sahel, and T1359. A Randomized Complete Block Design (RCBD) was used, with three replications for statistical robustness. Adults and larvae of *H. armigera* were collected from tomato fields and reared under laboratory conditions. Larvae were maintained on fresh tomato fruits at 27°C, while adults were held in cages at 25°C with access to a 10% honey solution to stimulate oviposition (Latha and Sharma, 2018).

Antixenosis assays

Two oviposition preference tests, free-choice and no-choice, were conducted, each with ten replicates per variety. Experiments were carried out under controlled laboratory conditions (25-30°C and 65-90% RH).

Free-choice test

Forty-day-old tomato plants were grown in pots and simultaneously placed in large multi-choice cages (80 × 70 × 60 cm) constructed with three glass walls and one muslin wall for ventilation. Each cage contained one plant of each variety (six in total), arranged randomly. A cotton pad soaked in 10% sucrose solution was provided as an adult food source. Thirty pairs of newly emerged *H. armigera* adults were released per cage and allowed to oviposit for three consecutive nights. Eggs were counted every three days. Glue barriers were applied to the table legs to prevent any interference (Ali et al., 2019).

No-choice test

For forced oviposition assessment, each variety was evaluated separately. One plant was placed per cage (dimensions as above) with ten replicates per variety. Ten pairs of adults were introduced per cage and allowed to oviposit for three nights. Eggs were counted every three days (Hu et al., 2018.

Oviposition assessment parameters

a) Number of eggs laid on each test variety
b) Total eggs laid on all varieties

c) Relative ovipositional preference (ROP):

$$ROP = \frac{\text{No. of eggs laid on test variety}}{\text{Total number of eggs laid on all test varieties}} \times 100$$

d) Selection of least and most preferred varieties for IPM purpose.

Electrical penetration graph (EPG) recording

Feeding behavior was assessed using a four-channel Giga-4 EPG system (EPG Systems, Netherlands) on both whole plants (WP) in soil and detached leaves (DL) placed in water-filled containers. Larvae were tethered with 20 µm gold wires using conductive silver glue and connected to the EPG amplifier. A copper electrode was placed in the soil or water reservoir. The setup was enclosed in a Faraday cage to reduce electrical interference. Feeding was recorded for five hours using Stylet + software at 100 Hz. Waveforms analyzed included:

C - Stylet activity in epidermis/mesophyll
E1 - Salivation into sieve elements
E2 - Phloem sap ingestion
F - Stylet derailment
G - Xylem ingestion

Statistical analysis

Antixenosis data were subjected to analysis of variance (ANOVA) using RCBD in Statistix 8.1. Means were compared using the Least Significant Difference (LSD) test at a 5% significance level (Sujana et al., 2008). EPG data were analyzed using the BAZ_V7.BETA Excel macro (Giordanengo, 2014). Parameters such as number of probes, total probing duration, pathway phase number and duration, and time to first probe were analyzed using one-way ANOVA to determine the effect of tomato variety under each treatment (whole plant and detached leaf). When significant differences were detected ($P < 0.05$), means were separated using Tukey's Honest Significant Difference (HSD) test.

Results

Oviposition behavior of *H. armigera* on tomato varieties

Free-choice test

Significant differences ($p < 0.05$) were observed among tomato varieties in terms of egg deposition (Table 1; Figure 1). The variety Rio Grande recorded the highest oviposition, with a mean of 324.5 eggs and a relative oviposition preference (ROP) of 24.8%, indicating strong susceptibility. Roma followed with 309.6 eggs (ROP = 23.7%), showing no significant difference from Rio Grande. Florida King was moderately preferred, with 265.4 eggs (ROP = 20.3%). Significantly fewer eggs were deposited on Red King (194.3 eggs, ROP = 14.8%) and T1359 (201.7 eggs, ROP = 15.4%). Sahel exhibited the lowest preference, with 150.9 eggs (ROP = 11.5%). These results suggest strong antixenotic resistance in Sahel and high susceptibility in Rio Grande (Table 1; Figure 1).

Table 1. Mean oviposition preference of *H. armigera* on selected tomato varieties in a free-choice test.

Varieties	Mean Number of Eggs	Standard Deviation (STD)	Rate of Oviposition (ROP)
Rio Grande	324.5 ± 8.32 a	26.34	24.8
Roma	309.6 ± 4.91 ab	15.52	23.7
Florida King	265.4 ± 7.42 bc	23.47	20.3
Red King	194.3 ± 12.36 cd	39.12	14.8
T1359	201.7 ± 11.64 cd	36.82	15.4
Sahel	150.9 ± 6.24 e	19.73	11.5

Means followed by the same letter(s) within a column are not significantly different according to Fisher's LSD test (α = 0.05).

No-Choice test

Consistent with the free-choice results, Rio Grande received the highest number of eggs (325.4, ROP = 24.9%) in the no-choice setup (Table 2; Figure 2). Roma (310.1 eggs, ROP = 23.8%) was similarly preferred. Florida King (275.2 eggs, ROP = 21.2%) ranked third. Red King (210.4 eggs, ROP = 16.1%) and T1359 (220.1 eggs, ROP = 16.5%) remained less preferred, while Sahel again recorded the lowest oviposition (160.3 eggs, ROP = 12.1%). This reinforced Sahel's status as the least favorable host for oviposition, likely due to deterrent morphological or chemical traits.

Feeding Behavior via Electrical Penetration Graph (EPG)

As per Table 3, EPG analysis revealed significant variation in feeding activity among tomato varieties under whole plant (WP) conditions. The number of probes (n) was highest for Rio Grande and significantly greater than for Red King and Sahel ($p = 0.028$), while differences under detached leaf (DL) conditions were non-significant ($p = 0.112$). Total probing duration (min) was longest on Rio Grande, followed by Florida King and Roma under WP conditions ($p = 0.042$), with Red King showing the shortest duration. DL results were non-significant ($p = 0.115$).

Table 2. Mean oviposition preference of *H. armigera* on selected tomato varieties under no-choice test.

Varieties	Mean Number of Eggs	Standard Deviation (STD)	Rate of Oviposition (ROP)
Rio Grande	325.4 ±7.60 a	24.5	24.9
Roma	310.1 ± 5.00 ab	15.75	23.8
Florida King	275.2 ± 7.20 bc	22.9	21.2
Red King	210.4 ± 10.90 cd	34.2	16.1
T1359	220.1 ± 9.70 cd	30.8	16.5
Sahel	160.3 ± 6.10 e	19.3	12.1

Means followed by the same letter(s) within a column are not significantly different according to Fisher's LSD test (α = 0.05).

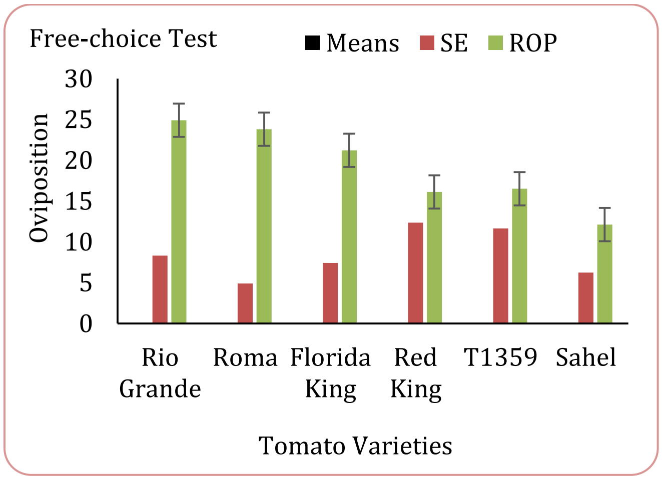

Figure 1: Ovipositional preference of *H. armigera* in six selected tomato varieties (Free-choice test).

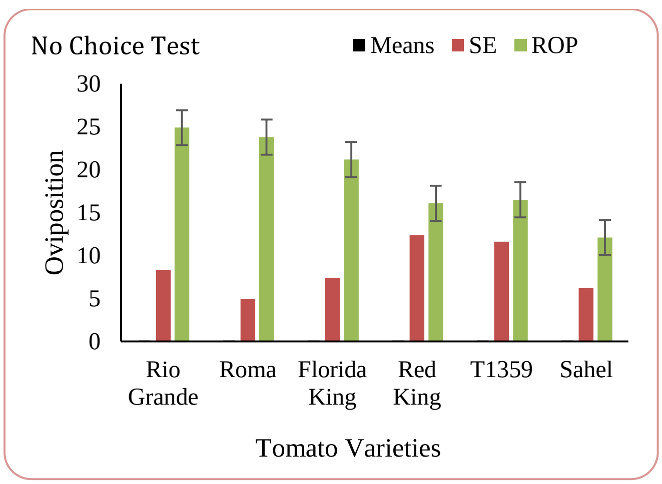

Figure 2. Ovipositional preference of *H. armigera* in six selected tomato varieties (No-choice test).

The number and duration of pathway phases followed a similar trend, with significant differences under WP (p = 0.035 and p = 0.017, respectively), again favoring Rio Grande for pest activity, while DL results were non-significant. Time to first probe showed no significant differences in either condition (WP: p = 0.731; DL: p = 0.882), indicating similar host contact initiation (Figure 3). Overall, both oviposition and feeding behavior assays consistently identified Rio Grande as the most preferred and Sahel as the least preferred variety by *H. armigera*. These findings are critical for Integrated Pest Management (IPM) planning, highlighting the potential of incorporating antixenosis-based resistance into variety selection strategies.

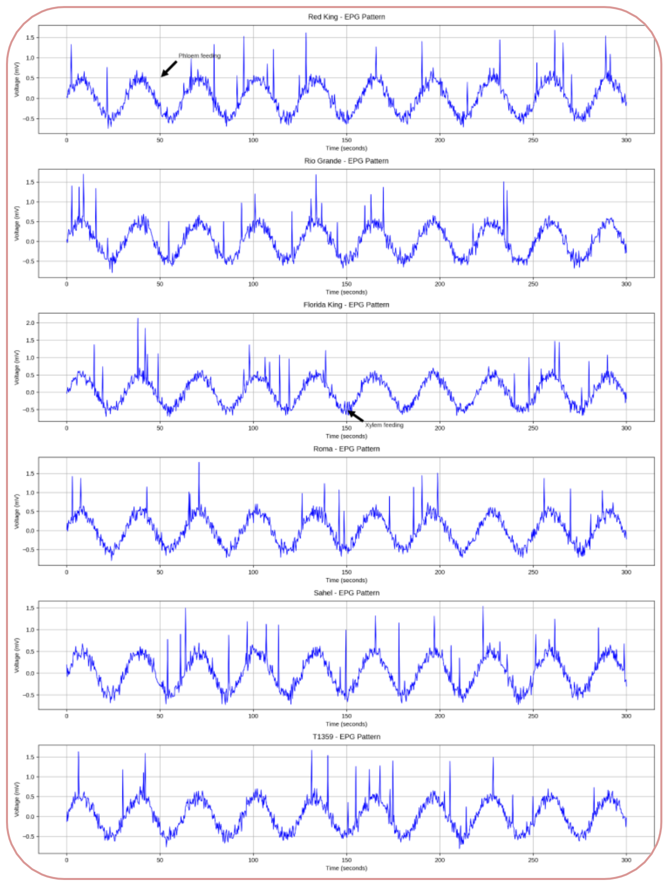

Figure 3. Electrophysiological analysis of the feeding behavior of *H. armigera* on six tomato varieties.

Table 3. Feeding behavior parameters of *H. armigera* on different tomato varieties.

Feeding Behavior Parameters	Varieties	Red King	Rio Grande	Florida King	Roma	Sahel	T1359	P-value
Number of Probes (n)	WP	12.4 ± 1.8 (8.3–16.5)	19.8 ± 2.3 (14.6–25.0)	15.6 ± 2.0 (11.1–20.1)	18.2 ± 2.1 (13.4–23.0)	14.3 ± 1.9 (10.0–18.6)	13.7 ± 1.7 (9.9–17.5)	0.028
	DL	278.5 ± 10.2 (255.4–301.6)	298.2 ± 8.9 (278.1–318.3)	285.6 ± 9.5 (264.1–307.1)	292.1 ± 7.6 (274.9–309.3)	276.8 ± 11.4 (251.0–302.6)	280.2 ± 8.8 (260.3–300.1)	0.042
Total Duration of Probing (min)	WP	14.7 ± 2.1 (9.9–19.5)	22.3 ± 3.1 (15.3–29.3)	18.4 ± 2.7 (12.3–24.5)	20.8 ± 2.9 (14.2–27.4)	16.9 ± 2.4 (11.5–22.3)	15.6 ± 2.3 (10.4–20.8)	0.035
	DL	140.5 ± 15.3 (105.9–175.1)	201.8 ± 18.6 (159.7–243.9)	171.9 ± 14.7 (138.6–205.2)	190.6 ± 17.3 (151.5–229.7)	152.3 ± 16.2 (115.7–188.9)	147.8 ± 14.5 (115.0–180.6)	0.017
Number of Pathway Phase (n)	WP	0.4 ± 0.3 (−0.3–1.1)	0.2 ± 0.1 (−0.0–0.4)	0.3 ± 0.2 (−0.2–0.8)	0.1 ± 0.1 (−0.1–0.3)	0.5 ± 0.4 (−0.4–1.4)	0.4 ± 0.3 (−0.3–1.1)	0.731
	DL	12.4 ± 1.8 (8.3–16.5)	19.8 ± 2.3 (14.6–25.0)	15.6 ± 2.0 (11.1–20.1)	18.2 ± 2.1 (13.4–23.0)	14.3 ± 1.9 (10.0–18.6)	13.7 ± 1.7 (9.9–17.5)	0.028
Total Duration of Pathway Phase (min)	WP	278.5 ± 10.2 (255.4–301.6)	298.2 ± 8.9 (278.1–318.3)	285.6 ± 9.5 (264.1–307.1)	292.1 ± 7.6 (274.9–309.3)	276.8 ± 11.4 (251.0–302.6)	280.2 ± 8.8 (260.3–300.1)	0.042
	DL	14.7 ± 2.1 (9.9–19.5)	22.3 ± 3.1 (15.3–29.3)	18.4 ± 2.7 (12.3–24.5)	20.8 ± 2.9 (14.2–27.4)	16.9 ± 2.4 (11.5–22.3)	15.6 ± 2.3 (10.4–20.8)	0.035
Time from Start to First Probe (min)	WP	140.5 ± 15.3 (105.9–175.1)	201.8 ± 18.6 (159.7–243.9)	171.9 ± 14.7 (138.6–205.2)	190.6 ± 17.3 (151.5–229.7)	152.3 ± 16.2 (115.7–188.9)	147.8 ± 14.5 (115.0–180.6)	0.017
	DL	0.4 ± 0.3 (−0.3–1.1)	0.2 ± 0.1 (−0.0–0.4)	0.3 ± 0.2 (−0.2–0.8)	0.1 ± 0.1 (−0.1–0.3)	0.5 ± 0.4 (−0.4–1.4)	0.4 ± 0.3 (−0.3–1.1)	0.731

WP = Whole plant; DL = Detached leaf; P-value: Indicates significance (for significant difference, ns for non-significant difference). Means followed by the same letter in the same row are not significantly different according to LSD test at α = 0.05.

Discussion

Host preference and oviposition behavior of *H. armigera*

Results from both free-choice and no-choice assays revealed significant variation in the oviposition behavior of *H. armigera* across tomato cultivars. 'Rio Grande' and 'Roma' consistently received the highest number of eggs, indicating strong oviposition preference, whereas 'Sahel' and 'Red King' were least preferred. This differential preference suggests potential host plant resistance or susceptibility and supports the hypothesis that host plant traits influence pest behavior. Thakur et al. (2018) reported that the distribution and density of glandular trichomes, along with compounds such as undercannon and tridecanon, can modulate *H. armigera* preference for specific tomato varieties.

Our findings align with earlier studies on host preference. For example, Sarfraz et al. (2019) observed similar varietal differences in *H. armigera* oviposition on soybean, highlighting the generality of such preferences across crops. Although morphological and biochemical traits were not directly measured in this study, literature strongly suggests that factors such as trichome density, cuticular wax properties, and secondary metabolites (e.g., methyl ketones, flavonoids, alkaloids) significantly influence oviposition (Junior et al., 2018; Tabary et al., 2024). High trichome density often exerts mechanical deterrence, whereas certain volatiles may attract or repel ovipositing females.

Future work should integrate morphological analyses (e.g., trichome mapping, leaf surface characterization) and phytochemical profiling (e.g., GC-MS analysis of volatile and non-volatile compounds) to identify traits responsible for antixenosis. Such mechanistic insights could guide breeding programs for pest-resistant cultivars.

Feeding behavior insights from EPG analysis

EPG data supported the host preference patterns observed in oviposition assays. Under WP conditions, significant differences were found in feeding parameters, including number of probes, total probing time, and pathway phase duration. 'Rio Grande' exhibited the highest feeding activity, consistent with its high oviposition preference, whereas 'Red King' and 'Sahel' showed reduced probing and shorter pathway phases, correlating with lower egg deposition. These results suggest a relationship between antixenosis and feeding deterrence, consistent with findings by Hu et al., (2018).

No significant variation was detected under DL conditions, indicating that intact plant cues, such as volatile organic compounds (VOCs), leaf morphology, or surface chemistry, play a critical role in modulating feeding behavior. Detached leaves likely fail to replicate the multi-sensory cues of whole plants, explaining the uniform pest response, a phenomenon also reported by Jacobson and Kennedy (2014).

Comparative context and implications for IPM

This study confirms earlier reports of host-specific oviposition in *H. armigera* (Sarfraz et al., 2019) and extends them by combining behavioral and electrophysiological approaches. The integration of oviposition assays with EPG monitoring provides a more comprehensive understanding of varietal susceptibility than oviposition data alone.

From an IPM perspective, cultivars such as 'Sahel' and 'Red King', which exhibit resistance to both oviposition and feeding, represent promising candidates for breeding programs. In contrast, susceptible varieties such as 'Rio Grande' and 'Roma' may require increased monitoring and targeted interventions, including pheromone trapping or biological control.

Limitations and future directions

Although this study identifies clear patterns of varietal preference in *H. armigera*, it remains descriptive rather than mechanistic, highlighting the need for future research to quantify leaf surface traits such as trichomes and waxes, characterize volatile and non-volatile compounds influencing insect behavior, conduct field validation to confirm whether laboratory trends hold under natural conditions, and explore genetic markers associated with resistance traits. Integrating laboratory screening with molecular and field confirmation will ultimately accelerate the development of tomato lines with durable, broad-spectrum resistance to *H. armigera*.

Conclusions

This study demonstrates clear varietal differences in the oviposition and feeding patterns of *H. armigera* on six tomato cultivars under controlled laboratory conditions. 'Rio Grande' and 'Roma' consistently emerged as the most susceptible varieties, exhibiting the highest egg deposition and larval feeding activity, whereas 'Sahel' and 'Red King' displayed strong antixenotic responses, with significantly lower egg deposition and reduced larval feeding, indicative of potential resistance traits. The integration of behavioral assays with Electrical Penetration Graph analysis provided a robust and comprehensive assessment of host plant preference, with the observed consistency between feeding and oviposition data reinforcing the validity of the findings and underscoring the importance of antixenosis in pest resistance screening. Although the morphological and biochemical traits responsible for the observed resistance were not quantified, the results offer a strong foundation for identifying key plant characteristics associated with reduced pest preference. This research is directly relevant to breeding programs aimed at developing pest-resistant tomato varieties and to the implementation of varietal-based strategies within IPM frameworks.

Recommendations

Future research should focus on quantitatively characterizing morphological traits (e.g., trichome density, cuticular structures) and phytochemical attributes (e.g., secondary metabolites, volatile organic compounds) in tomato cultivars to identify specific factors contributing to antixenosis against *H. armigera*. Laboratory findings should be validated under open-field conditions to assess the consistency of pest responses across environments and to account for biotic and abiotic interactions absent in controlled settings. 'Sahel' and 'Red King' should be prioritized as parental lines in breeding programs for developing pest-resistant cultivars, with marker-assisted selection used to enhance the efficiency of breeding pipelines. Conversely, susceptible varieties such as 'Rio

Grande' and 'Roma' should be cultivated alongside improved pest monitoring and management strategies, including pheromone traps, trap cropping, and biological control agents, to mitigate damage. A multidisciplinary approach integrating entomology, plant physiology, molecular biology, and agronomy will be essential for establishing sustainable and ecologically sound management solutions for *H. armigera* in tomato production systems.

Authors' Contributions

RUH conceived and conducted the experiments, prepared the materials, collected and analyzed the data. AURS supervised the study and assisted in data interpretation. Both authors contributed to the manuscript preparation, proofread, and approved the final version.

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Conflict of Interest

The authors declare no conflict of interest.

Sustainable Development Goals Targeted

SDG 2: Zero Hunger
SDG 12: Responsible Consumption and Production
SDG 15: Life on Land

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