ANTIBIOSIS AND ANTIXENOSIS IN TOMATO GENOTYPES AGAINST *Helicoverpa armigera* HUBNER †

[ANTIBIOSIS Y ANTIXENOSIS EN GENOTIPOS DE TOMATE CONTRA *Helicoverpa armigera* HUBNER]

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SUMMARY

Background. Farmers rely on the use of synthetic insecticides in managing *Helicoverpa armigera*, hole-boring insect pest on tomato, but they are detrimental to human health. Therefore a more reliable and ecofriendly control measure is needed such as host plant resistance**. Objective**. To assess the mechanisms of resistance in tomato varieties: NGB00724, NGB00724, Anaya, Kelvin, Mona, Roma VF (susceptible varieties), Tropimech and UC82B in laboratory and screen house. **Methodology**. Second larval instars were fed with leaves of the different tomato varieties and their development was observed till adult stage. Study was done in the screen house where number of larvae and eggs were also observed. Larval period and weight, and percentage adult emergence were assessed in tomato varieties. Metabolites (phenol, flavonoids, terpenoids, protein, reducing sugars and total sugars) in tomato leaves were determined following standard procedures. **Results**. *Helicoverpa armigera* fed with tomato leaves, Anaya recorded the lowest larval period (9.67 days). Also, larvae fed on Anaya and Mona had the lowest larval weight (0.19 g and 0.25 g). Also significantly lower percentage of adult emergence was observed on Anaya and Mona (16.7%) Mona, NGB00725 and Anaya significantly harbored the lower number of *Helicoverpa armigera* adult (0.1, 0.4, 0.4). The lowest number of eggs (0.5) was recorded from adults placed on Anaya variety. There was high and negative significant correlation of r = -0.865 between phenols and adult emergence. Phenols and oviposition were significantly negatively correlated (r = -0.816). **Implication.** Anaya and Mona hinder the development of *Helicoverpa armigera* larvae when fed on it. Phenol has negative impact on the development and oviposition of *Helicoverpa armigera*. **Conclusion**. It was revealed through this study that availability of promising resistant varieties can effectively combat the damage caused by *Helicoverpa armigera* and lessen the shortcomings related with the application of conventional chemical insecticides in tomato production.

Key words: Host-plant resistance; Oviposition; Primary Metabolites; Secondary Metabolites; Adult emergence.

RESUMEN

Antecedentes. Los agricultores dependen del uso de insecticidas sintéticos para controlar *Helicoverpa armigera*, una plaga de insectos perforadores de agujeros en el tomate, pero son perjudiciales para la salud humana. Por lo tanto, se necesita una medida de control más confiable y respetuosa con el medio ambiente, como la resistencia de la planta hospedera. **Objetivo.** Evaluar los mecanismos de resistencia en variedades de tomate: NGB00724, NGB00724, Anaya, Kelvin, Mona, Roma VF (variedades susceptibles), Tropimech y UC82B en laboratorio e invernadero. **Metodología.** Las larvas en segundo instar se alimentaron con hojas de las diferentes variedades de tomate y se observó su desarrollo hasta la etapa adulta. El estudio se realizó en el invernadero, donde también se observaron el número de larvas y huevos. Se evaluaron el período larval y el peso, y el porcentaje de emergencia de adultos en variedades de tomate. Los metabolitos (fenoles, flavonoides, terpenoides, proteínas, azúcares reductores y azúcares totales) en las hojas de tomate se determinaron siguiendo procedimientos estándar. **Resultados.** *Helicoverpa armigera* alimentada con hojas de tomate, Anaya registró el período larval más corto (9,67 días). Además, las larvas alimentadas con Anaya y Mona tuvieron el menor peso larval (0,19 g y 0,25 g). También se observó un porcentaje significativamente menor de emergencia de adultos en Anaya y Mona (16,7%). Mona, NGB00725 y Anaya albergaron significativamente el menor número de adultos de *Helicoverpa armigera* (0,1, 0,4, 0,4). El menor número de huevos

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(0.5) se registró en adultos colocados en la variedad Anaya. Hubo una correlación alta y negativa significativa de r = -0.865 entre los fenoles y la emergencia de adultos. Los fenoles y la oviposición estuvieron significativamente correlacionados de manera negativa (r = -0.816**). Implicación.** Anaya y Mona dificultan el desarrollo de las larvas de *Helicoverpa armigera* cuando se alimentan de ellas. Los fenoles tienen un impacto negativo en el desarrollo y la oviposición de *Helicoverpa armigera*. **Conclusión.** Este estudio reveló que la disponibilidad de variedades resistentes prometedoras puede combatir eficazmente el daño causado por *Helicoverpa armigera* y disminuir las deficiencias relacionadas con la aplicación de insecticidas químicos convencionales en la producción de tomate.
Palabras clave: Resistencia de la planta hospedera; Oviposición; Metabolitos primarios; Metabolitos secundarios; Emergencia de adultos

INTRODUCTION

Tomato, an important vegetable with appreciable quantities of vitamins A, B and C are essential for human growth (Reddy *et al*., 2023). Among the important nutritional contents in tomato fruit is lycopene which is an important antioxidant that lowers the risk of prostate cancer in men (Dube *et al*., 2020). Danuta *et al*. (2020) reported that processed tomato products like pizza sauce, tomato juice, spaghetti sauce, paste and ketchup provide 80% of the lycopene found in food. Tomato production is hampered by insect pests that reduce its yield and increases the cost of production (Mantzoukas and Karnastasi, 2019). *Helicoverpa armigera* belongs to insect family noctuidae and order lepidoptera. It is a nightmare to tomato farmers and is attracted to tomato plant during the flowering and fruiting stages (Pavunraj *et al*., 2021). Tomato fruitborer lays eggs on tomato leaves and soon after hatching the first instar larva feeds on tomato foliage. The second and older instars infest and damage tomato fruits, penetrate the fruits through the stem end, feed inside creating a watery hole (Omotoso and Alabi, 2023). Usually, the damaged fruits ripe prematurely or rot due to secondary invasion of fungal diseases hence damage of *H. armigera* constitutes a serious threat to tomato production (Sharma *et al*., 2009).

In the quest to control this pest of economic importance and salvage this important crop from *H. armigera* damage. Although, the use of conventional chemical insecticide provided a succour to the farmers by lessen the damage on tomato caused by *H. armigera* (Latha *et al*., 2018). However, the relief is short-lived due to snags associated with the use of synthetic chemical insecticides (Yadav, *et al*., 2022) such as a threat to the health of the growers and consumers, harmful impact on beneficial and non-target organism and development of resistance to the chemical insecticides (Ramadan *et al*., 2020). All these necessitate the application of eco-friendly control option in the management of *H. armigera* on tomato.

Planting of crops that are resistant to insect pest is among the most promising ways to reduce dependence on synthetic insecticides (Erdogan *et al*., 2020). Reports from previous researchers have shown that planting of insect-resistant varieties is part of the most effective, cost-effective and environmentally safe management tactics in controlling insect pests (Villegas *et al*., 2021). However, there is dearth of information in exploring resistant varieties and its mechanism for the management of *H. armigera* on tomato varieties. This study seeks to elucidate the mechanisms of resistance in different tomato genotypes and determine the phytochemicals that induce their resistance in tomato varieties.

MATERIALS AND METHODS

Study location

The experiment was conducted at the Insect Chemical Ecology Laboratory, Department of Crop Protection and Environmental Biology, University of Ibadan, Nigeria.

Helicoverpa armigera culture

Larvae of tomato fruit borer were collected from established insecticide-free tomato field. The collected larvae were reared on fresh leaves of tomato; they were placed singly in a plastic container (7.0 cm diameter x 5.2 cm height) with a lid to avoid cannibalism. The lid was punctured randomly with a pin for proper aeration. Fresh young tomato leaves were placed in the plastic container and changed daily to maintain proper sanitation. When the larvae were fully grown, it pupated. After pupation, the pupae were transferred into another container (19.3 cm diameter x 18.2 cm height) that served as oviposition chamber. A paper towel was positioned at the base of the oviposition chamber and the pupae were placed on the paper towel. A white mesh was placed on the oviposition chamber and held with the lid that was cut with a circular open for proper aeration. Thereafter, those pupae that jiggled were placed on the paper towel using forceps. Immediately after adult emergence, 10% honey was placed in a small tube covered with cotton wool which served as food for the adult *H. armigera*. The adult mated and laid eggs on the white mesh in the oviposition chamber. The white

mesh was removed and replaced with a new one daily. The white mesh with eggs was put in a zip up bag. Oxygen was allowed in the zip up bag for the neonates.

Source of seeds

Tomato seeds NGB00724 and NGB00725 were sourced from National Center for Genetic Resources and Biotechnology. UC82B and Roma VF (Susceptible check) were sourced from National Horticultural Research Institute while Anaya, Mona, Kelvin and Tropimech, were from Agritropic Limited, all in Ibadan, Oyo State, Nigeria. The tomato genotypes were selected based on farmers preferred choice.

Evaluation of antibiosis of tomato varieties

Under no choice test, the experiment was set up using completely randomized design with six replicates. There were eight treatments in this experiment, with each corresponded to a genotype of tomato: NGB00724, NGB00724, Anaya, Kelvin, Mona, Roma VF (susceptible varieties), Tropimech and UC82B. Seven best performed varieties were selected from the previous experiment due to their consistent lower rate of *Helicoverpa armigera* percentage fruit damage (1.03 – 18.00) and the susceptible check with 36.80 percentage fruit damage (Omotoso and Alabi, 2023).

Fourty-eight second instar larvae of *Helicoverpa armigera* due to the tender nature of first laval instar were transferred from the culture with brush into a plastic container (7.0 cm diameter x 5.2 cm height) each with a pierced lid. The lid was punctured eight times with a pin. Eight tomato genotypes: NGB00724, NGB00724, Anaya, Kelvin, Mona, Roma VF (susceptible varieties), Tropimech and UC82B that were insecticide-free were earlier established on the field and used for this experiment. Eight weeks after transplanting, third tomato leaves from the upper part of each genotype mentioned above were introduced into the experimental set up. The study was conducted under laboratory condition (temperature: 31.8 ^{o}C, relative humidity: 67% and photoperiod: Light 12: Dark 12). The experimental set up was observed daily for pupation and mortality, the leaves were changed daily to maintain sanitation till pupation period of the larvae. A tube containing 10% honey was placed in a small tube covered with cotton wool served as food for the adult (Sujana *et al*., 2012).

Antixenosis of tomato genotypes to *Helicoverpa armigera*

Antixenosis was evaluated under choice test using tomato plants set up in the Screenhouse of the Department of Crop Protection and Environmental Biology, University of Ibadan, Nigeria. Those eight tomato genotypes earlier used for antibiosis experiment were used for this experiment. The experiment was laid out using a randomized complete block design with six replicates. Sandy-loam soil of 10 kg was filled into a plastic pot (24.5 cm diameter x 21.7 cm height) placed in the screenhouse.

Four-week-old tomato seedlings from the nursery were carefully taken and transplanted at the rate of one seedling per pot in the evening after all pots were filled with sandy-loam soil. All pots were watered with 1.5 L of water between 17: 00 and 18: 00 hrs. One week after transplanting missing stands were supplied with tomato seedlings from the nursery and the potted plants in each replicate were placed in an enclosed fine mesh. The plants were well supported with erect wooden bars to prevent the enclosed mesh from damaging the stem of the tomato plants in the pots; watering was done daily. Five pairs of adult *H. armigera* from the insect culture (one male: one female) were released into the enclosed mesh for seven days and no fertilizer was applied. A tube containing 10% honey was placed in a small tube covered with cotton wool served as food for the adults (Sujana *et al*., 2012).

Determination of Primary and secondary metabolites in tomato genotypes

Extraction Procedures

Tomato leaves of: Anaya, NGB00724, NGB00725, Mona, Kelvin, Tropimech, UC82B, Roma VF (Susceptible check) were obtained from the established tomato field eight weeks after transplanting. Third tomato leaf samples from the upper part of plant were collected and put in a well labelled envelop; the samples were stored in freezer until extraction.

Sugar Content Determination

Determination of the total sugar content in tomato leaves was done by the method described by Dubois *et al*. (1956). The technique described by Saad *et al*. (2021) was used to determine the reducing sugar content of tomato leaves.

Determination of Phenolic, Flavonoids and Protein contents

Total phenolic content of tomato leaves extracts was measured using the Folin–Ciocalteu reagent method described by Kaur and Kapoor (2002). The aluminum chloride colorimetric method, as reported by Hashemi

et al. (2021), was used to determine the total flavonoid content of tomato leaf extracts. The protein content was determined by Kjeldahl method described by Sakar *et al*. (2020).

Data collection

Data were collected on the following parameters during antibiosis experiment: larval weight, larval period, pupal weight, pupal period, adult longevity and percentage pupation. While the number of eggs on the plants and the number of larvae on each plants were collected from antixenosis study.

Data analysis

Analysis of Variance (ANOVA) was performed using DSAASTAT statistical software (ver. 1.101 2011). Significant means were separated using Newman-Keuls Multiple Range Test at $p < 0.05$.

RESULTS

Antibiosis of tomato genotypes to tomato fruitworm, *Helicoverpa armigera*

Significant differences ($p < 0.05$) were shown in the larva weight (g) and larval period (days) as presented in Table 1. Roma VF (Susceptible Check) recorded highest (0.46 ± 0.17 g) larval weight, while the lowest value (0.19 ± 0.04 g) was from Anaya. The same result trend was observed in larval period where Roma VF (SC) had the highest value (14.83 ± 0.17 days) with no significant differences ($p > 0.05$) from other genotypes except Mona and Anaya.

Results on pupa weight (g) (Table 2) revealed Roma VF (SC) having highest value (0.32 ± 0.01 g) with no significant differences ($p > 0.05$) from other tomato genotypes accept Anaya F1 with significant difference ($p < 0.05$): whereby Anaya recorded the lowest (0.17 ± 0.04 g). For pupa period (Days) and pupation (%) there were no significant differences amongst the treatments (Table 2).

Adult emergence (days) and longevity (days) of *Helicoverpa armigera* fed on different tomato genotypes were showed in Table 3. All the genotypes supported *Helicoverpa armigera* to adult but in varied degree. The lowest percentage of adult emergence (16.7 ± 11.18) was observed on Anaya and Mona and were significantly lower ($p = 0.05$) than others. Roma VF (Susceptible variety), Tropimech, and NGB00725 recorded the highest adult longevity (6.00 ± 1.21 days, 5.00 ± 1.59 days, 4.00 ± 1.29 days, respectively) with no significant difference ($p > 0.05$) from Roma VF (susceptible variety).

Antixenosis of tomato genotypes to tomato fruitworm, *Helicoverpa armigera*

Results on Table 4 revealed the number of *Helicoverpa armigera* adult and oviposition. The lowest number of *Helicoverpa armigera* adult (0.1 ± 0.04) was obtained on Mona with a significantly lower value ($p = 0.05$) than Roma VF, susceptible variety. Roma VF had the highest number of eggs (7.2 ± 1.09). While Anaya had the lowest number of eggs (0.5 ± 0.016) and was significantly lower ($p = 0.05$) than the susceptible variety.

Secondary metabolites (mg/100g) in tomato leaves of different tomato genotypes

The phenolic, flavonoids and terpenoids contents in genotypes of tomato leaves are shown in Table 5. Phenolic content ranged from (254.0 ± 4.16 mg/100g) on Anaya to (206.5 ± 7.03 mg/100g) on NGB00725. Flavonoid content ranged from (144.0 ± 4.0 mg/100g) on Anaya to (55.3 ± 0.08 mg/100g) on Roma VF, a susceptible check. Terpenoids ranged from (56.4 ± 0.03 mg/100g) on susceptible check to (45.4 ± 0.05 mg/100g) on NGB00725.

Table 1. Development parameters of *Helicoverpa armigera* larvae on tomato genotypes.

Genotype	Larval weight (g)	Laval Period (Days)
NGB00725	0.35 ± 0.14bcd	14.67 ± 0.21b
Anaya	0.19 ± 0.04a	9.67 ± 1.94a
Kelvin	0.41 ± 0.17cd	13.83 ± 0.31b
Mona	0.25 ± 2.45ab	11.00 ± 2.20ab
Roma VF (SC)	0.46 ± 0.17d	14.83 ± 0.17b
Tropimech	0.33 ± 0.15bc	14.00 ± 0.37b
UC82B	0.32 ± 0.13bc	13.67 ± 0.21b

Means in a column followed by the same letter(s) are not significantly different at $p > 0.05$ using Newman-Keuls Multiple Range Test. Values are means ± S. E. of three replicates
SC = Susceptible Check

Table 2. Pupa weight and period of *Helicoverpa armigera* on tomato genotypes.

Genotype	Pupal weight (g)	Pupal period (Days)	Percentage pupation (%)
NGB00725	0.28 ± 0.01b	6.67 ± 2.12	66.7 ± 21.08
Anaya	0.17 ± 0.04a	7.17 ± 1.45	50.0 ± 22.36
Kelvin	0.31 ± 0.03b	6.33 ± 2.03	66.7 ± 21.08
Mona	0.31 ± 0.03b	8.17 ± 1.66	50.0 ± 22.36
Roma VF (SC)	0.32 ± 0.01b	5.50 ± 2.47	83.3 ± 16.67
Tropimech	0.27 ± 0.01b	5.83 ± 1.85	66.7 ± 21.08
UC82B	0.29 ± 0.01b	6.17 ± 2.77	83.3 ± 16.67

Means in a column followed by the same letter(s) are not significantly different at p > 0.05 using Newman-Keuls Multiple Range Test. Values are means ± S. E. of three replicates
SC = Susceptible check

Table 3. Adult emergence and longevity of *Helicoverpa armigera* on tomato genotypes.

Genotype	Adult emergence (%)	Adult longevity (Days)
NGB00724	50.0 ± 8.36ab	1.83 ± 1.22ab
NGB00725	66.3 ± 10.54ab	4.00 ± 1.29abc
Anaya	16.7 ± 10.54a	0.67 ± 0. 57a
Kelvin	50.0 ± 8.33ab	3.67 ± 1.65abc
Mona	16.7 ± 11.18a	0.83 ± 0.73a
Roma VF (SC)	83.3 ± 11.18b	6.00 ± 1.21c
Tropimech	66.7 ± 10.54ab	5.00 ± 1.59bc
UC82B	66.7 ± 8.33ab	3.67 ± 1.17abc

Means in a column followed by the same letter(s) are not significantly different at p > 0.05 using Newman-Keuls Multiple Range Test. Values are means ± S. E. of three replicates
SC = Susceptible check

Table 4. Mean number of *Helicoverpa armigera* eggs and adults on of different tomato genotypes.

Genotype	Number of Adult	Oviposition
NGB00724	0.5 ± 0.13a	3.2 ± 0.85c
NGB00725	0.4 ± 0.07a	3.9 ± 0.98c
Anaya	0.4 ± 0.14a	0.5 ± 0.16a
Kelvin	0.8 ± 0.28ab	2.3 ± 0.42bc
Mona	0.1 ± 0.04a	1.1 ± 0.25ab
Roma VF (SC)	1.7 ± 0.29c	7.2 ± 1.09d
Tropimech	1.5 ± 0.37bc	6.0 ± 1.15d
UC82B	0.6 ± 0.38a	2.9 ± 0.42c

Means in a column followed by the same letter(s) are not significantly different at p > 0.05 using Newman-Keuls Multiple Range Test. Values are means ± S. E. of three replicates
SC = Susceptible check

Percentage sugar and protein contents in genotypes of tomato leaves

The highest percentage of protein content (24.1 ± 0.11 mg/100g) was recorded from UC82B which was significantly different (p < 0.05) from the susceptible check (21.7 mg/100) (Table 6). Protein contents ranged from 22.8 ± 0.21 mg/100g on Mona to (20.0 ± 0.11 mg/100g) on Kelvin and Anaya. The highest similar percentages of 0.5 % of reducing sugars were obtained on Mona, Kelvin and Roma VF (susceptible check). The lowest percentage of reducing sugars (0.3 ± 0.03% each) were observed on NGB00725 and Mona, respectively with a significant difference (p = 0.05) from the susceptible check. Percentages of total sugar content ranged from (2.2 ± 2.39%) on UC82B to (1.8± 0.35%) on Anaya.

Correlation of primary and secondary metabolites in genotypes of tomato leaves with percentage pupation, adult emergence and oviposition

There was negative correlation between phenolics and pupation (r = -0.684) and was not significant (Table

7). The correlation between flavonoids and pupation was negative and not significant (r = 0.742) (p = 0.05). Protein and pupation was positively correlated and non-significant (r = 0.427) (p = 0.05). Pupation and reducing sugar and terpenoids were positively correlated and non-significant.

Phenolics was negatively correlated with adult emergence (r = -0.865) and was significant. There was also negative correlation (r = -0.715) between flavonoids and adult emergence. The correlation between total sugar and adult emergence was positive (r = 0.938) and significant. Terpenoids and adult emergence was positively correlated (r = 0.032) and non-significant. There was a negative correlation between phenolics and oviposition (r = 0.816) and was significant. There was a positive correlation between flavonoid and oviposition (r = 0.646) and was significant. Protein and oviposition was positively correlated (r = 0.282) and non-significant. The correlation of oviposition and reducing sugar and terpenoid was positive and non-significant. Total sugar and oviposition was positively correlated and significant (r = 0.827).

DISCUSSION

Antibiosis mechanism of resistance impairs an insect's metabolic processes. Most times, ingestion of plant metabolites is involved. In this study, reduced larval weight and period were observed on *H. armigera* fed on Anaya tomato variety. This could be attributed to differences in the nutrition contents of each tomato variety as revealed through varied levels of larval weights and periods (Coelho *et al.*, 2019). This is similar to Kouchi *et al.* (2014) that reported varied feed conversion efficiency among *H. armigera* larvae fed with different tomato varieties with Rio grande recorded the lowest feed conversion efficiency of tomato. This is also in consonance with Krisnawati *et al.* (2017) that reported the evaluation of soyabean genotypes for antibiosis against armyworm through reduced weight of the larvae and duration and stated high antibiosis on genotype G511H/Anj-1-6 with the lowest larval weight.

Table 5. Secondary metabolites (mg/100g) in tomato leaves of different tomato genotypes.

Genotype	Phenolic content (mg/100g)	Flavonoids (mg/100g)	Terpenoids (mg/100g)
NGB00724	215.0 ± 9.94a	118.7 ± 1.52c	47.3 ± 0.05a
NGB00725	206.5 ±7.03a	119.4 ± 4.17c	45.4 ± 0.05a
Anaya	254.0 ± 4.16a	144.0 ± 2.40d	46.7 ± 0.04a
Kelvin	229 ± 4.73ab	77.5 ± 5.75b	52.5 ± 0.02b
Mona	232.5 ± 2.38ab	123.7 ± 0.45c	47.5 ± 0.04a
Roma VF (SC)	208.5± 8.20a	55.3 ± 0.29a	56.4 ± 0.03b
Tropimech	213.2 ± 1.63a	59.2 ± 0.58a	55.3 ± 0.08b
UC82B	217.9 ± 6.17a	64.5 ± 1.47a	55.3 ± 0.04b

Means in a column followed by the same letter(s) are not significantly different at p > 0.05 using Newman-Keuls Multiple Range Test. Values are means ± S. E. of three replicates
SC = Susceptible Check

Table 6. Percentage sugar and protein contents in tomato leaves of different tomato genotypes.

Treatment	Protein (mg/100g)	Reducing sugar (%)	Total sugar (%)
NGB00724	20.5 ± 0.28a	0.4 ± 0.02a	2.0 ± 0.05b
NGB00725	20.9 ± 1.02ab	0.3 ± 0.03a	2.1 ± 0.92b
Anaya	20.0 ± 0.11a	0.4 ± 0.02a	1.8 ± 0.35a
Kelvin	20.0 ± 0.19a	0.5 ± 0.02ab	2.1 ± 0.49b
Mona	22.8 ± 0.21c	0.3 ± 0.03a	1.9 ± 0.98a
Roma VF (SC)	21.7 ± 0.23ab	0.5 ± 0.02ab	2.1 ± 0.56b
Tropimech	22.7 ± 0.11bc	0.5 ±0.01ab	2.2 ± 1.73b
UC82B	24.1 ± 0.11c	0.5 ± 0.01ab	2.2 ± 2.39b

Means in a column followed by the same letter(s) are not significantly different at p > 0.05 using Newman-Keuls Multiple Range Test. Values are means ± S. E. of three replicates
SC = Susceptible Check

Table 7. Correlation of primary and secondary metabolites in different genotypes of tomato leaves with percentage pupation and adult emergence of *Helicoverpa armigera*.

	Phenol	Flavonoids	Protein	Reducing sugar	Total sugar	Terpenoids	Pupation	Adult emergence	Oviposition
Phenol	1.00								
Flavonoids	0.49	1.00							
Protein	-0.336	-0.537	1.00						
R. sugar	-0.36	-0.795*	0.175	1.00					
Total sugar	- 0.795*	-0.896*	0.476	0.56	1.00				
Terpenoids	-0.039	-0.645	0.759*	0.397	0.365	1.00			
Pupation	-0.684	-0.742	0.427	0.575	0.868*	0.178	1.00		
A.emergence	-0.865*	-0.715	0.283	0.437	0.938**	0.032	0.874*	1.00	
Oviposition	-0.816*	0.646	0.282	0.34	0.827*	0.125	0.549	0.844	1.00

* Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed).
R. sugar = Reducing sugar, Phenol = Phenolic content, A. emergence = Adult emergence

Anaya tomato variety had the lowest larval period which translates to reduction in the damage caused when compared with others that recorded lengthy days. This could be due to imbalances in the quality and quantity of primary and secondary metabolites require for optimum larval growth and could be an important factor in conferring antibiosis on tomato (Gacemi *et al*., 2022). Although, the pupal stage is the resting and changing stage where feeding does not take place. However, the amount and quality of food consumed during the larval stage affects pupation and emergence of adult. This was shown in the elongated pupal period obtained on Mona, Anaya and NGB00725. This gave a clue to the effect of antibiosis as it increased the duration of time spent during inactive period, delaying the development and decreases the damage done to the tomato plant. This agrees with Ngugi-Dawit *et al*. (2020) that indicated that delay in the development of insect pest is a promising indicator of an antibiosis mechanism of defence. Therefore, the low pupation rate observed on larvae that fed on Anaya showed the insect's metabolic processes had been impaired. Also, it is worthy of mention that half of the population of the larvae fed on Anaya and Mona pupated. This indicates a high level of antibiosis to *H. armigera*.

Lower percentage of adult emergence and longevity observed on larvae fed with Anaya and Mona indicated the apparent antibiosis resistance mechanism operating within these two genotypes. It may be due to the presence of secondary metabolites in optimum amount that have detrimental effect on the percentage of adult emergence. Low level of adult emergence observed on Anaya and Mona affects the population dynamics of the next generation, this retards the pest population. This is similar to de Castro *et al*. (2015) that reported different responses in the biology of *Supputius cincticeps* fed on different plants including tomato leaves. The results obtained of this study also show the existence of ample genetic variation among tomato genotypes to provide improved varieties in advancement to insect pest management (Javaid, 2006).

In the antixenosis study, the relatively low number of *Helicoverpa armigera* adults that settled on Mona, NGB00725 and Anaya indicated low acceptance by *H. armigera* for shelter. This could be as a result of genetical and morphological variability of the genotypes that deter settling and utilizing those genotypes for oviposition by *H. armigera* (Kamel and El-Gengaihi, 2009). Therefore, the strongest antixenosis resistance is observed on Mona which attracted lowest number of *H. armigera* (Kirişik *et al*., 2020). In the same vein, oviposition diminished on Mona and Anaya due to the inability to suitably utilize it for shelter. This suggests that there are biophysical and biochemical factors that impair oviposition behavior and also elicit different responses from different varieties of tomato plants to *Helicoverpa armigera*. Smith (2005) also indicated presence of some morphological characters (pubescence, foliage size and shape) in Cucumis species that makes *Aphis gossypii* look for an alternate host plant.

The studies further examined primary and secondary metabolites of the observed tomato genotypes. Secondary metabolites such as phenolic compounds present in plants confer properties such as antifeedant by repelling phytophagous insects (Talukder *et al*., 2021). Mrosso *et al*. (2022) indicated that flavonoids are toxic to whiteflies, thus protecting tomato plants from their infestation and damage. Therefore, it can be inferred from this study that the varieties that showed resistance to *H. armigera* had some secondary metabolites liable for the resistance in Anaya F1, the most resistant variety, has 75.3 mg/100 flavonoids and 183.9 mg/100 phenol. This aligns with Golan *et al*. (2017) that observed secondary metabolites preventing oviposition of insect on host plant and disrupt larval growth. This results also corroborates with the findings of Dixit *et al.* (2017) that indicated that phenolic compounds are toxic to insects and act as

feeding deterrents to a wide range of insects including lepidopteran larvae.

It is anticipated that genotypes with higher level of total sugar and reducing sugar would enhance susceptibility of *H. armigera* damage. In the present study, resistant genotypes, Anaya, Mona and NGB00724 recorded relatively lower level of total sugar and reducing sugar. This agrees with Sun *et al*. (2021) that reported that sugars and protein are phagostimulants that induce sustained feeding in insect herbivores. However, from the results obtained in this study, those genotypes that showed resistance contained higher levels of protein than the susceptible control, Roma VF. This corroborates with Alabi *et al*. (2006) that reported higher levels of protein in the floral buds and flowers of resistant cultivars of cowpea to *Megalorothrips sjostedti* than Vita 7, the susceptible control.

In this study, highly significant negative correlation observed between phenolic content and adult emergence suggested a clue in safe and ecofriendly management of *H armigera*. Phenolic content was also negatively correlated with oviposition, this suggests the promising impact of phenol content to impair the biology of insect. In this sense, gene coding for phenolic content can be explore to induce resistance to *H. armigera.* This agrees with Puri *et al*. (2020) who reported the ability of phenol content to undermine the physiology of insect pest and confirmed phenol stability for use in the management of insect pest. This also suggests that role of phenol in plant resistance is very important in plant defense system preventing crops from the invasion of insects (Ramaroson *et al*., 2022).

CONCLUSION

The results of this study shows the existence of variation in the quantity of metabolites among tomato genotypes to provide improved varieties in advancement to insect pest resistance in the field of crop protection. Furthermore, it is noteworthy to recognize susceptible genotypes to *H. armigera* to prevent over-reliance and snags associated with the use of synthetic insecticides in the management of *H. armigera*. It was observed from the findings of these studies that biochemical compounds can be used in the management of *H. armigera*. It shows that secondary metabolites, phenol and flavonoids can be explore in the management of *H. armigera* affecting tomato yield on farmers' field. In addition, biochemicals are the results of primary and secondary metabolic processes which serve as feeding stimulants or deterrents. Some of the secondary metabolites such as phenol function as mechanisms for chemical defense against *H. armigera* infestation on tomato fruits. This is a good omen for farmers as insect-resistant crop varieties can enhance the livelihoods of farmers, particularly those regions that are heavily dependent in agriculture. Farmers can have more consistent yields, higher incomes, safe food and greater resilience to insect-pest related risks. This can help uplift the farmers out of poverty and contribute to rural development.

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