Field evaluation of tomato (*Solanum lycopersicum* L.) varieties for resistance to tomato fruit borer (*Helicoverpa armigera* Hubner) in southwestern Nigeria

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This appraisal of tomato varieties against tomato fruit borer (*Helicoverpa armigera)* was conducted in replicated field trials during the late seasons of 2020 and 2021. The 20 tomato varieties and accessions comprised: Alausa Long, Anaya F1, Ibadan Local, Kelvin F1, Mona F1, NGB00696, NGB00713, NGB00722, NGB00723, NGB00724, NGB00725, NGB00737, Panther-17, Rio Grande, Rodeo-62 F1, Roma Savanna, Roma VF (Susceptible check), Tima, Tropimech and UC82B. Anaya F1, Rio Grande, Mona F1, NGB00724 and UC82B had the lowest number of larvae/plant (0.04, 0.04, 0.05, 0.06, and 0.07) over the 2 years. Anaya F1, Mona F1 and NGB00725 showed the lowest mean percentage of fruit infestation (1.0, 4.7 and 13.1%), respectively. During the first year, Alausa Long, Mona F1 and Kelvin F1 had the highest fruit yields (30.7, 30.2 and 29.4 kg/ha, respectively), while Anaya F1, NGB00725 and Rio Grande had the highest yields (27.6, 16.4 and 15.9 kg/ha, respectively) during the second year. The correlations between pericarp thickness and both number of larvae and mean percentage of fruit damage (r = -0.827, -0.802, respectively) were negative and significant. It was observed during the study that none of the varieties/accessions was free from the *Helicoverpa armigera* attack. However, Anaya F1, Mona F1 and NGB00724 performed better with minimal *Helicoverpa armigera* larval infestation and had higher yields.

Keywords: Tomato, *Helicoverpa armigera*, resistance, tomato varieties, yield

Tomato is one of the most sought after vegetables worldwide (Bisht et al. 2019) because it contains an appreciable quantity of vitamins A, B and C (Priyanka et al. 2018). Lycopene, an important antioxidant obtained from tomatoes, fights against prostate cancer in men (Biswas et al. 2020). With the immense importance of tomatoes in diets and high demand by agro-allied industries, yields are still low worldwide, and needs are unmet (Osipitan et al. 2017; Monika et al. 2022). The production and expected yield of tomatoes are constrained and threatened by several biotic and abiotic factors, including infestation of insect pests (Kumar et al. 2020). Tomato is affected by an array of insect pests; the lepidopteran *Helicoverpa armigera* (tomato fruit borer) has been a significant challenge, and its infestation has caused a colossal loss to farmers in tomato production (Yadav et al. 2022).

The *Helicoverpa armigera* moths are attracted to tomato plants, especially during the flowering and fruiting stages (Ewedairo et al. 2020). The adult lays eggs on tomato leaves, and soon after hatching, the first instar feeds on tomato leaves (Reddy et al. 2020). The second instar attacks fruits at the premature stage and enters the fruit through the stem end. It feeds inside the fruit, creating a watery cavity (Islam et al. 2020). Usually, the damaged fruits ripen prematurely and become unmarketable or rot due to a secondary pathogen invasion (Monika et al. 2022).

In the effort to control the pest, farmers have used chemical control methods to manage *Helicoverpa armigera* (Kamal et al. 2019). Synthetic insecticides decimate insect pest activities but are expensive (Alabi et al. 2012; Ibrahima et al. 2021). Their frequent and high use culminates in pest resistance to different types of insecticides, as well as phytotoxicity and health hazards to the farmers (Reddy et al. 2020). Destruction of beneficial organisms such as predators, parasitoids, microorganisms and pollinators are among the problems (Deb et al. 2019).

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As a result of the drawbacks that result from the use of chemical insecticides, the recent approach of dealing with pest problems has shifted to economical and environmentally sound techniques (Kumar et al. 2020). Screening for resistant varieties has been the first line of defence and the key to reducing pest population and loss due to the infestation of *Helicoverpa armigera* (Bisht et al. 2019). Hence, there is a need to determine *Helicoverpa armigera* resistant tomato varieties and accessions to reduce the reliance on chemical insecticides. Therefore, this study used replicated field trials to identify tomato varieties and accessions resistant to *Helicoverpa armigera* from a total of 20 varieties developed from cultivation in Nigeria.

Materials and methods

Source of seeds

The tomato seeds of Roma VF (susceptible check) and UC82B were sourced from Premier Seeds, Ibadan. Ibadan Local and Alausa Long were sourced from National Horticultural Research Institute, Ibadan. Anaya F1, Mona F1, Kelvin F1, Roma Savanna, Tropimech, Rodeo 62 F1, Rio Grande, Tima and Panther 17 were sourced from Agritropic Limited, Ibadan, while NGB00725, NGB00724, NGB00722, NGB00713, NGB00737, NGB00723 and NGB00769 were sourced from the National Centre for Genetic Resources and Biotechnology, Ibadan.

Study location

The experiment was conducted at Akinmorin, Oyo State during the late seasons of November 2019 - February 2020 in the first year and November 2020 - February 2021 in the second year. The study site is geographically located at 7^{o}45' N, 3^{o}56 E. During the first year the average temperature was around 23.2 - 25.7^{o}C, relative humidity was 70% and precipitation was 0.5 mm and in second year average the temperature was around 25.2 - 26.5^{o}C, relative humidity was 72% and precipitation was 0.4 mm.

Tomato seedlings raised in a nursery

Sandy-loam soil was placed in circular bowls of 47 cm diameter and 7 cm in height, and tomato seeds were broadcast on the soil to raise seedlings. The soil was weed-free, seedlings were irrigated daily for 30 days, and no chemical control measure was applied.

Land preparation and transplanting of seedlings

A land area of 63 x 12 m was cleared, and 60 beds measuring 2 x 2 m were carefully prepared. The spacing between each bed and each block was 1 m and a 2 m border was maintained around the entire set of beds. All the tomato beds were mulched with dry straw of 0.15 m thickness to retain the moisture content of the soil. The Roma VF, a susceptible variety of tomatoes, was grown around each bed as spreader rows for *Helicoverpa armigera* 2 weeks before planting the main crops at the spacing of 50 cm between each plant. Four-week-old tomato seedlings were carefully transplanted to the beds at 50 cm between rows and 50 cm within rows on the edge of each bed. Tomato seedlings were transplanted into the prepared field in the evening after all the beds were watered between 17:00 - 18:00 hrs. No protection measure was used. Each bed had a total number of 16 tomato plants at one plant per stand. One week after transplanting, gaps were filled with tomato seedlings from the nursery. In both years the field was laid out in a randomised complete block design with three replicates of each of the 20 varieties. Tomato plants were staked 3 weeks after transplanting, and the plots were weeded manually using a hoe. Watering of plots occurred between 17:00 - 18:00 hrs daily using a watering can. Protection measures were not enforced on the crops during the field trials.

Assessment of biophysical characters of tomato varieties

Stem diameter, pericarp thickness, and fruit diameter were assessed using a digital caliper (15 cm). Plant height was assessed with the use of a measuring tape. The number of leaves and number of locules were obtained by counting. The data were observed from ten randomly selected plants for each variety in each of the replicates from 14 days after planting till fruiting.

Appraisal of tomato plants against *Helicoverpa armigera*

The same ten tomato plants in each plot were observed weekly for the presence and infestation of *Helicoverpa armigera*. The number of larvae/plant, total number of fruit and number of healthy fruit per plant were assessed. The fruits were harvested five times between 85 - 120 days after planting and grouped into damaged and healthy, based on the presence and absence of *Helicoverpa armigera* entry and exit holes. The percentage of fruit damage was calculated. Each variety was later categorised using the resistance scale developed by Safna et al. (2018) and described in Table 1.

Table 1: Mean grading system for *Helicoverpa armigera* damage in tomatoes

Percentage fruit damage	**Category**
Damage free	Highly resistant
0.1 – 10%	Resistant
10.1 - 20.0%	Moderately resistant
20.1 - 30.0%	Moderately susceptible
30.1 - 40.0%	Susceptible
40.1% and above	Highly susceptible

Source: Safna et al. 2018.

Data analysis

All the data were analysed with analysis of variance using DSAASTAT statistical software (ver. 1.101 2011). Significant means were separated using Newman-Keuls Multiple Range Test at $P \leq 0.05$. Correlation analyses were performed to assess the relationship between the mean percentage of damaged fruits and morphological features of tomatoes.

Results

Morphological characters of different tomato varieties/accessions

Morphological characters at 14 days after planting of different appraised tomato varieties/accessions in 2020 and 2021 are presented in Table 2. The highest mean number of leaves (23.13) was recorded on NGB00725. There was a significant difference ($P \leq 0.05$) between the varieties with highest number of leaves and the susceptible control (Table 2). Anaya F1 had the lowest number (6.61) of leaves and was not significantly different ($P > 0.05$) from the susceptible control. There was no significant difference ($P > 0.05$) between the varieties for the stem diameter. Kelvin F1 had the highest plant height (48.22 cm); it was significantly higher ($P \leq 0.05$) than Roma VF, the susceptible control. Anaya F1 recorded the lowest plant height (20.19 cm) and was not significantly different ($P > 0.05$) than the susceptible control. Ibadan Local had the highest number of locules (9.03) and was significantly different ($P \leq 0.05$) from the susceptible control. The lowest pericarp thickness (0.07 cm) was recorded on NGB00722, while the highest was recorded on NGB00737 and Rio Grande. Anaya F1 had the highest fruit diameter (3.43 cm) while NGB00724 had the lowest fruit diameter (1.88 cm).

Table 2: Morphological characters of different tomato varieties/accessions screened in southwestern, Nigeria in the late seasons against *Helicoverpa armigera* in 2020 and 2021

Tomato variety	Number of leaves	Stem diameter (cm)	Plant height (cm)	Number of locules	Pericarp thickness (cm)	Fruit diameter (cm)
Alausa Long	20.11 ± 0.32f	0.51 ± 0.00a	47.61 ± 0.17g	2.23 ± 0.07a	0.18 ± 0.01cd	2.14 ± 0.01b
Anaya F1	6.61 ± 0.13a	0.41 ± 0.01a	20.19 ± 0.65a	3.57 ± 0.04c	0.27 ± 0.01efgh	3.43 ± 0.03i
Ibadan Local	22.93± 0.34f	0.62 ± 0.01a	37.28 ± 0.23efg	9.03 ± 0.07f	0.13 ± 0.04ac	3.21 ± 0.01h
Kelvin F1	13.96 ± 0.16cd	0.74 ± 0.07a	48.22 ± 1.25g	3.27 ± 0.04bc	0.22 ± 0.01defgh	2.30 ± 0.02c
Mona F1	7.62 ± 0.09ab	0.49 ± 0.01a	24.38 ± 0.53a	3.43 ± 0.07bc	0.25 ± 0.01defgh	3.42 ± 0.01i
NGB00696	19.05 ± 0.20ef	0.55 ± 0.00a	29.40 ± 0.17abcd	3.36 ± 0.01bc	0.08 ± 0.01a	2.09 ± 0.01b
NGB00713	13.76 ± 0.24cd	0.54 ± 0.01a	28.29 ± 0.79abc	3.60 ± 0.02c	0.21 ± 0.01cdef	3.17 ± 0.01h
NGB00722	15.72 ± 0.16de	0.49 ± 0.00a	23.71 ± 0.17a	3.00 ± 0.01b	0.07 ± 0.02a	2.00 ± 0.01b
NGB00723	20.35 ± 1.06f	0.53 ± 0.01a	39.45 ± 1.17efg	3.33 ± 0.05bc	0.21 ± 0.01cdef	3.17 ± 0.01h
NGB00724	17.84 ± 0.48ef	0.53 ± 0.01a	36.68 ± 0.38cef	3.40 ± 0.06bc	0.22 ± 0.01defgh	1.88 ± 0.01a
NGB00725	23.13± 0.70f	0.43 ± 0.00a	43.01 ± 0.05fg	3.47 ± 0.07bc	0.21 ± 0.02cdef	2.08 ± 0.05b
NGB00737	10.91 ± 0.33abc	0.50 ± 0.01a	25.06 ± 0.53ab	3.47 ± 0.04bc	0.29 ± 0.00fh	2.35 ± 0.01c
Panther-17	7.82 ± 0.14ab	0.52 ± 0.01a	33.90 ± 0.77bcde	3.47 ± 0.04bc	0.29 ± 0.00fh	3.09 ± 0.01b
Rio Grande	8.02 ± 0.08ab	0.58 ± 0.00a	27.09 ± 0.49ab	4.13 ± 0.04d	0.98 ± 0.01i	2.48 ± 0.01d
Rodeo-62 F1	11.10 ± 0.43bcd	0.66 ± 0.01a	28.74 ± 0.99abcd	5.83 ± 0.04e	0.08 ± 0.00ab	2.29 ± 0.01c
Roma Savanna	8.46 ± 0.38ab	0.57 ± 0.00a	20.31 ± 0.34a	2.57 ± 0.05a	0.21 ± 0.01cdef	2.69 ± 0.01eg
Roma VF (SC)	8.34 ± 0.11ab	0.56 ± 0.01a	20.50 ± 0.66a	2.60 ± 0.31a	0.18 ± 0.01cd	2.52 ± 0.01d
Tima	11.64 ± 0.23bcd	0.62 ± 0.01a	23.23 ± 0.57a	3.37 ± 0.05bc	0.20 ± 0.00cde	2.25 ± 0.01de
Tropimech	10.13 ± 0.31abc	0.54 ± 0.00a	28.56 ± 0.22abc	3.63 ± 0.04c	0.21 ± 0.01cdefgh	2.63 ± 0.01defg
UC82B	8.24 ± 0.02ab	0.69 ± 0.08a	22.22 ± 0.59a	2.26 ± 0.10a	0.24 ± 0.01defgh	2.55 ± 0.07def
SEM	1.17	0.05	2.04	0.11	0.03	0.09

Means in a column followed by the same letter(s) are not significantly different (P > 0.05) using Student-Newman-Keuls test. Values are means ± SEM of 3 replicates. SC = susceptible check, SEM = Standard error of the means.

Number of larvae of *Helicoverpa armigera* per plant on tomato varieties

The study revealed various damage caused by *Helicoverpa armigera* larvae on tomato fruits throughout the field study (Table 3). In the first year, Ibadan local recorded the highest mean number of larvae per plant (0.31) with the lowest number recorded by Mona F1 and Rio Grande (0.06). During the second year, Anaya F1 harboured the lowest number of larvae/plant, however it was not significantly different (P > 0.05) from Roma VF (susceptible variety).

Averaged over both years, Ibadan Local harboured the highest larvae per plant (0.20), while larvae were fewer on Anaya F1 (0.04), Rio Grande (0.04), Mona F1 (0.05), NGB00724 (0.06) and UC82B (0.07). However, there was no significant difference (P > 0.05) in the number of larvae/plant between Ibadan local and several other varieties, including Roma VF (susceptible variety). The number of larvae/plant observed in the first year was slightly higher than in the second year.

Table 3: *Helicoverpa armigera* larval population/plant on tomato varieties in southwestern, Nigeria in the late seasons of the first (2020) and second (2021) years

Tomato variety	Number of larvae/plant		
	First year	Second year	Mean
Alausa Long	0.20 ± 0.02ab	0.09 ± 0.01abcd	0.15 ± 0.01abc
Anaya F1	0.07 ± 0.01a	0.01 ± 0.01a	0.04 ± 0.01a
Ibadan Local	0.31 ± 0.04b	0.09 ± 0.01abcd	0.20 ± 0.02c
Kelvin F1	0.15 ± 0.01ab	0.07 ± 0.01abcd	0.11 ± 0.01abc
Mona F1	0.06 ± 0.01a	0.04 ± 0.01abcd	0.05 ± 0.01ab
NGB00696	0.13 ± 0.01ab	0.11 ± 0.01abcd	0.12 ± 0.00abc
NGB00713	0.07 ± 0.01a	0.09 ± 0.01abcd	0.08 ± 0.01abc
NGB00722	0.11 ± 0.01a	0.13 ± 0.02cd	0.12 ± 0.01abc
NGB00723	0.20 ± 0.02ab	0.08 ± 0.02abcd	0.14 ± 0.01abc
NGB00724	0.07 ± 0.00a	0.04 ± 0.01abcd	0.06 ± 0.01ab
NGB00725	0.09 ± 0.01a	0.15 ± 0.01d	0.12 ± 0.01abc
NGB00737	0.22 ± 0.02ab	0.08 ± 0.01abcd	0.15 ± 0.01abc
Panther-17	0.17 ± 0.02ab	0.05 ± 0.01abcd	0.11 ± 0.01abc
Rio Grande	0.06 ± 0.01a	0.02 ± 0.02abc	0.04 ± 0.01a
Rodeo-62 F1	0.18 ± 0.01ab	0.06 ± 0.01abcd	0.12 ± 0.00abc
Roma Savanna	0.22 ± 0.01ab	0.03 ± 0.01abc	0.13 ± 0.00abc
Roma VF (SC)	0.23 ± 0.02ab	0.08 ± 0.01abcd	0.16 ± 0.01bc
Tima	0.19 ± 0.03ab	0.05 ± 0.01abcd	0.12 ± 0.01abc
Tropimech	0.12 ± 0.01ab	0.07 ± 0.01abcd	0.09 ± 0.01abc
UC82B	0.07 ± 0.01a	0.06 ± 0.01abcd	0.07 ± 0.01ab
SEM	0.07	0.03	0.05

Means in a column followed by the same letter(s) are not significantly different (P > 0.05) using Student-Newman-Keuls test. Values are means ± SEM. of 3 replicates. SC = susceptible check

Percentage of fruit damage of *Helicoverpa armigera* on tomato varieties

Table 4 reveals the percentage of fruit damaged in both years. During the first year, the highest percentage of fruit damage was recorded in Ibadan local (54.2%), but this was not significantly different (P > 0.05) from Roma VF (susceptible check) (32.3%). Anaya F1, Mona F1 and NGB00725 had the lowest percentages of fruit damaged (1.5, 1.8 and 6.9% respectively), but these values were not significantly different (P > 0.05) from Roma VF (susceptible check). In the second year the lowest percentage of fruit damaged were recorded on Anaya F1, NGB00724, Mona F1 and Kelvin F1 (0.6, 5.3, 7.5 and 11.4% respectively) and these values were significantly lower than Roma VF (susceptible check) (36.8%). Averaged over the 2 years, the lowest mean percentages of fruit damage were recorded on Anaya F1, Mona F1 and NGB00724 (1.0, 4.7 and 9.6% respectively) and these varieties/accessions were categorised as resistant varieties. Accessions NGB00725, Kelvin F1, UC82B and Tropimech had 13.1, 15.2, 16.0 and 18.0% percentage fruit damage averaged over the 2 years and were classified as moderately resistant. Roma Savanna, NGB00723, Roma VF (susceptible check), Panther-17 and NGB00722 were categorised as susceptible varieties. Highly susceptible varieties were NGB00696, Alausa Long, NGB00713, Ibadan Local, Tima, Rodeo-62 F1, NGB00737 and Rio Grande.

Table 4: Percentage of fruit damage of *Helicoverpa armigera* on tomato varieties in southwestern, Nigeria in the late seasons of the first (2020) and second (2021) years

	Percentage fruit damage			
Tomato variety	**First year**	**Second year**	**Mean of 2 years**	**Category**
Alausa Long	48.2 ± 3.45c	44.4 ± 0.70defg	46.3 ± 1.56e	Highly susceptible
Anaya F1	1.5 ± 0.23a	0.6 ± 0.18a	1.0 ± 0.19a	Resistant
Ibadan Local	54.2 ± 2.96c	56.5 ± 0.38efgh	55.3 ± 1.36e	Highly susceptible
Kelvin F1	19.0 ± 0.85abc	11.4 ± 1.34abc	15.2 ± 0.62abc	Moderately resistant
Mona F1	1.8 ± 0.57a	7.5 ± 0.63abc	4.7 ± 0.37a	Resistant
NGB00696	31.4 ± 2.52abc	56.5 ± 1.05efgh	43.9 ± 1.38de	Highly susceptible
NGB00713	50.5 ± 4.38c	44.5 ± 2.74 defg	47.5 ± 2.19e	Highly susceptible
NGB00722	32.6 ± 0.90abc	46.0 ± 1.05defg	39.3 ± 0.85cde	Susceptible
NGB00723	36.5 ± 2.39abc	35.3 ± 1.50cde	35.8 ± 1.94bcde	Susceptible
NGB00724	13.9 ± 0.05abc	5.3 ± 0.71ab	9.6 ± 0.35ab	Resistant
NGB00725	6.9 ± 0.64ab	19.4 ± 0.77abcd	13.1 ± 0.64abc	Moderately resistant
NGB00737	33.5 ± 2.82abc	84.4 ± 2.48h	58.9 ± 1.97e	Highly susceptible
Panther-17	34.1 ± 2.67abc	40.4 ± 0.40de	37.2 ± 1.44bcde	Susceptible
Rio Grande	56.8 ± 3.59c	70.8 ± 0.37fgh	63.7 ± 1.79e	Highly susceptible
Rodeo-62 F1	44.8 ± 1.96bc	72.1 ± 4.48gh	58.4 ± 3.18e	Highly susceptible
Roma Savanna	30.7 ± 0.57abc	32.8 ±1.30bcde	31.7 ± 0.38bcde	Susceptible
Roma VF (SC)	32.3 ± 1.38abc	41.5 ± 1.23def	36.8 ± 0.64bcde	Susceptible
Tima	51.1 ± 6.29c	63.4 ± 5.90efgh	57.2 + 6.09e	Highly susceptible
Tropimech	18.7 ± 1.37abc	17.4 ± 0.57abcd	18.0 ± 0.97abcd	Moderately resistant
UC82B	19.4 ± 2.76abc	12.7 ± 1.07abc	16.0 ± 1.56abc	Moderately resistant
SEM	8.11	6.49	6.82	

Means in a column followed by the same letter(s) are not significantly different (P > 0.05) using Student-Newman-Keuls test. Values are means ± SEM. of 3 replicates. SC = susceptible check.

The yield of tomato fruits of varieties appraised against *Helicoverpa armigera* infestation

The yields of different tomato varieties appraised against *Helicoverpa armigera* in 2 years are presented in Table 5. Averaging both years, Anaya F1, Roma Savanna and Alausa Long produced the highest yields (27.6, 23.8 and 22.4 kg/ha respectively). However, there was no significant difference (P > 0.05) between the yield of variety that produced the highest yield (Anaya F1) and the susceptible control and nine other varieties. UC82B and NGB00713 had the lowest yields (Both 7.1 kg/ha).

Table 5: Fruit yields (kg/ha) of tomato varieties appraised against *Helicoverpa armigera* in southwestern, Nigeria in the late seasons of the first (2020) and second (2021) years

Tomato variety	**Yield (kg/ha)**		
	First year	**Second year**	**Mean**
Alausa Long	30.7 ± 3.22ab	14.1 ± 2.03ab	22.4 ± 1.89bcd
Anaya F1	27.1 ± 0.60ab	27.6 ± 4.36b	27.6 ± 2.44d
Ibadan Local	24.3 ± 0.52ab	10.1 ± 1.07ab	17.2 ± 0.63abcd
Kelvin F1	29.4 ± 1.84ab	7.8 ± 0.43a	18.6 ± 0.89abcd
Mona F1	30.2 ± 1.86ab	11.7 ± 0.57ab	20.9 ± 1.21bcd
NGB00696	21.8 ± 2.14ab	13.1 ± 0.51ab	17.4 ± 0.83abcd
NGB00713	6.3 ± 1.38a	7.9 ± 2.34a	7.1 ± 0.76a
NGB00722	29.7 ± 4.51ab	5.9 ± 2.55a	17.8 ± 1.47abcd
NGB00723	23.0 ± 1.47ab	13.1 ± 0.75ab	18.0 ± 1.10abcd
NGB00724	5.0 ± 0.62a	13.0 ± 1.18ab	9.0 ± 0.66ab
NGB00725	5.0 ± 0.44a	16.4 ± 0.91ab	10.7 ± 0.58abc
NGB00737	13.7 ± 2.57ab	4.4 ± 2.43a	9.0 ± 0.41ab
Panther-17	24.07± 4.61ab	9.3 ± 1.12ab	17.0 ± 1.75abcd
Rio Grande	3.4 ± 0.62a	15.9 ± 1.90ab	9.7 ± 1.260ab
Rodeo-62 F1	27.4 ± 7.27ab	5.9 ± 2.68a	16.6 ± 2.61abcd
Roma Savanna	40.4 ± 1.75b	7.1 ± 3.83a	23.8 ± 1.10cd
Roma VF (SC)	22.7 ± 3.98ab	10.3 ± 1.05ab	16.5 ± 1.66abcd
Tima	16.8 ± 2.73ab	4.5 ± 1.23a	10.7 ± 1.93abc
Tropimech	24.0 ± 1.97ab	7.1 ± 2.38a	15.5 ± 1.40abcd
UC82B	10.0 ± 2.50a	4.2 ± 1.22a	7.1 ±0.64a
SEM	9.43	6.34	4.70

Means in a column followed by the same letter(s) are not significantly different (P > 0.05) using Student-Newman-Keuls test. Values are means ± SEM of 3 replicates. SC = susceptible check.

Correlation of the mean percentage fruit damage by *Helicoverpa armigera* with the morphological characters of tomato varieties

The correlation of the mean percentage fruit damage and morphological parameters of tomato varieties are given in Table 6. Highly significantly negative correlations were found between pericarp thickness and mean percentage fruit damage and mean number of larvae per plant (r = -0.802 and -0.827 respectively). There was high significant positive correlation (r = 0.804) between number of leaves and plant height. Highly significantly negative correlation (r = -0.828) was found between number of leaves and fruit diameter. The correlation (0.829) of pericarp thickness with fruit diameter was positive and significant.

Table 6: Correlation matrix for larval infestation and fruit damage by *Helicoverpa armigera* and morphological features of resistant tomato varieties in southwestern, Nigeria in late seasons of the first (2020) and second (2021) years

	Leaves	**Height**	**Locules**	**Pericarp**	**Diameter**	**Damage**	**Larvae**
Leaves	1.000						
Height	0.804*	1.000					
Locules	0.291	0.360	1.000				
Pericarp	-0.728*	-0.730*	0.163	1.000			
Diameter	-0.828*	-0.742*	0.103	0.829*	1.000		
Damage	0.303	0.433	-0.649	-0.802*	-0.645	1.000	
Larvae	0.709*	0.629	0.236	-0.827*	-0.636	0.714*	1.000

Leaves = number of leaves. Height = plant height. Locules = number of locules. Pericarp = pericarp thickness. Diameter = fruit diameter. Damage = mean percentage fruit damage. Larvae = mean population of larvae/plant.

* Significant at P ≤ 0.05 (2-tailed), df = 6

Discussion

Host plant resistance has proven to be a simple and reliable tool in crop protection. In the present study, the observed tomato varieties with different morphological characters showed a varied number of larvae/plant from 0.06 – 0.31 during the first year to 0.01 – 0.15 in the second year. Although few larvae colonised the tomato plants, it resulted in various levels of fruit damage by *Helicoverpa armigera*. This is in agreement with Bisht et al. (2019), who screened 21 varieties/germplasms of tomato during the rabi season in India. They found no variety/germplasm that was free from damage of *Helicoverpa armigera*. The cultivation during the rabi season is mainly through irrigation and similar to the late season in southwestern Nigeria. Selvanarayanan and Narayanasamy (2006) also had a similar result; they observed 0.20 - 0.30 larvae per plant in three different Indian varieties during the rabi season in India. The decrease in the number of larvae per plant observed during the second year of this research could be the result of environmental factors that affected insect population dynamics, abundance, distribution, and feeding behaviour (Khaliq et al. 2014).

There was a slight difference in the range of larvae/plant in the two years among screened varieties/accessions. This translated to different percentages of fruit damage across the varieties. This resulted in varied categories of fruit damage. The results revealed that only three varieties, Anaya F1, Mona F1 and NGB00724, were resistant, while NGB00696, Alausa Long, NGB00713, Ibadan Local, Tima, Rodeo-62 F1, GB00737 and Rio Grande were highly susceptible. This suggests that some tomato varieties exposed to a natural infestation by *Helicoverpa armigera* exhibited a certain tolerance level, while some were highly vulnerable. This conforms with Safna et al. (2018), who reported that no variety was absolutely free from damage of *Helicoverpa armigera* among the evaluated tomato varieties in Wakawali, India. Usman et al. (2013) observed that a similar number of *Helicoverpa armigera* per plant on screened varieties resulted in different levels of damage on the varieties.

Anaya F1, Mona F1 and NGB00724 proved to be the most promising of the screened varieties/accession of tomato. Amin et al. (2016) evaluated ten varieties of tomato against *Helicoverpa armigera* damage. Varieties BARI Tomato-11, BARI Tomato-10, BARI Tomato-15 and BARI Tomato-4 were classified as resistant varieties with percentage fruit damages of 3.6, 6.9, 7.3 and 9.5, respectively. The variation in different levels of damage may be a result of differences in the biophysical and biochemical factors of the tomato plants. This result aligns with Ashfaq et al. (2012), who reported varied responses of tomatoes to the damage of tomato fruit worms.

Anaya F1 and Mona F1 varieties had the lowest mean percentage of fruit damage and relatively good yields in both years. However, NGB00713 and UC82B had a consistently low yield in both years, although UC82B recorded relatively low fruit damage at 16.0%. This may be a result of some inherent traits in those accessions. Amin et al. (2016) reported that inherent characteristics of the varieties affect yield. Nasrin et al. (2020) also reported yield variation from different tomato varieties.

The present study revealed a positive correlation between the mean number of larvae per plant and mean percentage of fruit damage. This is in consonance with Zahid et al. (2008) and Amjad et al. (2013), who reported a positive correlation of larval population and the number of infested fruits.

There was also a negative and significant correlation between pericarp thickness and mean percentage fruit damage. This corroborates with the findings of Ambule et al. (2015) who also recorded a negative correlation between pericarp thickness and fruit damage. However, the result is in variance with Sharma and Bharadwaj (2009), who reported a positive correlation (r = 0.767) between pericarp thickness and fruit damage. This could be due to differences in the genetical constituents of the varieties screened during the experiments.

There was a negative and non-significant correlation between mean percentage fruit damage and fruit diameter. This is in conformity with Prasad et al. (2014), who found a negative correlation between fruit damage and fruit diameter in eggplants. This suggests that pericarp thickness and possibly fruit diameter are good biophysical bases of resistance that can be explored in combating damage by *Helicoverpa armigera* on tomato. Farmers could look for these biophysical qualities that reduce pest status of *Helicoverpa armigera* when selecting tomato varieties to plant. Also, breeders could determine the genes that code for these biophysical traits in these tomato varieties and insert the genes into farmer preferred varieties that are susceptible.

Conclusion

The appraised varieties were of varied categories of resistance status based on fruit damage from the rating scale for fruit borer infestation in tomatoes. Out of all the observed varieties, none was free from the damage of *Helicoverpa armigera*. However, the promising varieties and accessions from the study that were categorised as resistant or moderately resistant were Anaya F1, Mona F1, NGB00724, NGB00725, Tropimech, Kelvin F1 and UC82B. The most susceptible varieties were Alausa Long, Rio Grande, Rodeo-62 F1, NGB00696, NGB00713, NGB00737, Tima and Ibadan Local. There is a need to explore further the mechanisms of resistance operating in those varieties that performed better on the field as well as their yield potential. The use of resistant varieties would reduce the drawbacks of using chemicals to control *Helicoverpa armigera*.

References

Alabi, O. Y., E. Aziza, and A.A. Omoloye. 2012. “Preliminary Evaluation of Selected Cowpea Varieties for the Resistance to Cowpea Aphid, *Apis craccivora*.” *Nigerian Journal of Ecology* **12**:45–55.

Ambule, A.T., G.G. Radadia, D.L. Patil, and N.R. Toke. 2015. “Morphological Characters of Tomato in Relation to Resistance Against Tomato Fruit Borer, *Helicoverpa armigera* (Hubner).” *International Journal of Plant Protection* **8 (1)**: 152–156.

Amin, M.R., A. Chakma, M.Z. Alam, M.M. Hossain, and F. Ge. 2016. “Screening of Tomato Varieties Against Tomato Fruit Borer and Associated Plant Characters.” *Journal of Agriculture* **14 (2)**: 150–161.

Amjad, U., A.K. Imtiaz, I. Mian, U.R.S. Ahmad, and S. Maqsood. 2013. “Appraisal of Different Tomato Genotypes Against Tomato Fruitworm (*Helicoverpa armigera* Hubner) Infestation.” *Pakistan Journal of Zoology* **45 (1)**: 113–119.

Ashfaq, M., M. Sajjad, M.N. Ane, and N. Rana. 2012. “Morphological and Chemical Characteristics of Tomato Foliage as Mechanisms of Resistance to *Helicoverpa armigera* (Hubner) (Lepidoptera: *Noctuidae*) Larvae.” *African Journal of Biotechnology* **11**:7744–7750.

Bisht, K., N.N. Singh, and S.V.S. Raju. 2019. “Evaluation of Comparative Resistance in Tomato Varieties/Germplasms Against Fruit Borer, *Helicoverpa armigera* (Hubner).” *Journal of Entomology and Zoology Studies* **7 (5)**: 581–588.

Biswas, M.S., M.S. Hossain, M.Z. Alam, Y.J. Kwon, and S.J. Suh. 2020. “Bio-Rational Management Approaches of Fruit Borer, *Helicoverpa armigera* (Hübner) Infesting Tomato.” *Bangladesh Journal of Agricultural Resources* **45 (1)**: 11–20.

Deb, S., and T.M. Bharpoda. 2019. “Field Evaluation of Biopesticides Against *Helicoverpa armigera* (Hubner) Hardwick in Tomato, *Lycopersicon esculentum* Mill. under Middle Gujarat Condition.” *Journal of Green Farming* **8 (1):** 188–19.

Ewedairo, B., A.A. Osipitan, A.R., Popoola, L.O. Sanni, and M.I. Takeet. 2020. “Molecular Identification of *Helicoverpa armigera* (Hubner) Associated with Tomatoes (*Solanum lycopersicum* L.) in

Ogun State." *Nigerian Journal of Biotechnology* **37 (1)**: 46–54.

Ibrahima B.A., A. Ndiaye, D. Dicko, M. Faye, and M. Sembene. 2021. "Comparative Efficacy of Two Bio-Insecticides in the Fight Against *Helicoverpa armigera* (Hubner, 1808) (Lepidoptera: Noctuidae) Pest of Crops." *International Journal of Biological and Chemical Science* **15 (5):** 1875–1883.

Islam, M.K., M.T.H. Howlader, and K.S. Ahmed. 2020. "Management of *Helicoverpa armigera* (Hubner) Infesting Tomato using Biopesticides Under Field Condition and its Effect on Tomato Yield." *Journal of Bangladesh Agricultural University* **18 (1)**: 1–5.

Kamal, M.M., S. Das, M.H. Sabit, and D. Da. 2019. "Efficacy of Different Management Practices Against Tomato Fruit Borer, *Helicoverpa armigera* Hubner." *Bangladesh Journal of Agricultural Resources* **44 (2):** 339–353.

Khaliq, A., M. Javed, M. Sohail, and M. Sagheer. 2014. "Environmental Effects on Insects and Their Population Dynamics." *Journal of Entomology and Zoology Studies* **2 (2)**: 1– 7.

Kumar, K., S. Pal, and Y.K. Devi. 2020. "Morpho-physical Characteristic in Tomato Imparting Resistance to Sucking Pest Whitefly, *Bemisia tabaci* (Gennadius) Aleyrodidae: Hemiptera." *Journal of Emerging Technologies and Innovative Research* (JETIR) **7 (12)**: 2349–5162.

Kumar, S., R.S. Umrao, A. Kumar, V.K. Patel, R. Debnath, and A. Kumar. 2020. "Evaluation of the Efficacy of Insecticides and Biopesticides Against *Helicoverpa armigera* (Hubner) on Tomato." *Journal of Entomology and Zoology Studies* **8 (3)**: 555–558.

Monika, Singh M., P. L. Sharma, and I. K. Kasi. 2022. "Incidence of Major Insect Pest Infesting Tomato in Low and Mid Hills of Himachal Pradesh." *The Pharma Innovation Journal* **11 (8):** 1888–1890.

Nasrin S., M.A. Mannan, M.M. Islam, and S.A.U. Khan. 2020. "Evaluation of Tomato Varieties Against Resistance to Fruit Borer (*Helicoverpa armigera* Hubner)." South Asian Association for Regional Cooperation (SAARC) *Journal of Agriculture* **18 (2)**: 87–99.

Osipitan, A.A., A.R. Popoola, B.I. Ewedairo, A. Fagbenro, A. Adeoti, and O.W. Adabale, 2017. "Influence of Morphological Characters of Thirteen Accessions of Tomato (*Solanum lycopersicum* L.) Fruits on Damage by the Tomato Fruitworm *Helicoverpa armigera* Hubner (Lepidoptera: Noctuidae)." *Nigerian Journal of Ecology* **16 (1)**: 1–13.

Prasad, T.V., R. Bhardwaj, K.K. Gangopadhyay, M. Arivalagan, M.K. Bag, B.L. Meena, and M. Dutta. 2014. "Biophysical and Biochemical Basis of Resistance to Fruit and Shoot Borer (*Leucinodes obnalis* Guennee) in Eggplant." *Indian Journal of Horticulture* **71 (1)**: 67–71.

Priyanka, T., R.S. Rana, K.C. Sharma, and N. Sharma. 2018. "Host Preference of the Fruit Borer, *Helicoverpa armigera* (Hubner) on Tomato Varieties in Mid Hills of Himachal Pradesh." *Journal of Entomology and Zoology Studies* **6 (1)**: 1186–1189.

Reddy, K.V.N., A. Vyas, G. Chhangani, and M. Jat. 2020. "Monitoring of Tomato Fruit Borer (*Helicoverpa armigera*) in Relation to Abiotic Factors in Udaipur." *Journal of Entomology and Zoology Studies* **8 (4)**: 2276–2278.

Safna, M., V.N. Kumud, P.B. Sanap, and M. Allada. 2018. "Screening of Tomato Cultivars Against Fruit Borer *Helicoverpa armigera* (Hubner) Infesting Tomato." *Journal of Entomology and Zoology Studies* **6 (2)**: 2053–2055.

Selvanarayanan,V., and P. Narayanasamy. 2006. "Assessment of Tomato Germplasm for Resistance to Fruit Borer *Helicoverpa armigera* (Hubner)." *Journal of Vegetable Science* **11 (12)**: 71–79

Sharma, K.C., and S.C. Bharadwaj. 2009. "Influence of Phenological and Physical Characters of Tomato on Fruit Borer, *Helicoverpa armigera* (Hubner) Infestation." *Resistant Pest Management Newsletter* **19 (1)**: 46–48.

Usman, A., I.A. Khan, M. Inayatullah, A.U.R. Saljoqi, and M. Shah. 2013. "Appraisal of Different Tomato Genotypes against Tomato Fruit Worm (*Helicoverpa armigera* Hubner) Infestation." *Pakistan Journal of Zoology* **45 (1)**:113–119

Yadav, S.P.S., V. Lahutiya, and P. Paudel. 2022. "A Review on the Biology, Ecology, and Management Tactics of *Helicoverpa armigera* (Lepidoptera: Noctuidae)." *Turkish Journal of Agriculture – Food Science and Technology* **10 (12)**: 2467–2476.

Zahid, M.A., M.M. Islam, M.H. Rezma, H.Z. Prodhan, and M.R. Begum. 2008. "Determination of Economic Injury Levels of *Helicoverpa armigera* (Hubner) in Chickpea." *Bangladesh Journal of Agricultural Resources* **33:**555– 563.