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Antixenosis and Antibiosis Basis of *Leucinodes orbonalis* (G.) Resistance in Commercial Brinjal Genotypes

Sarvadaman S. Udikeri[1]*, L Hanumantharaya[2], Jayalaxmi Narayan Hegde[1], Sadashiv Nadukeri[1] and D Lakshmana[1]

[1]*College of Agriculture, Navile, Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka, India.*
[2]*Zonal Agricultural and Horticultural Research Station, Babbur Farm, Hiriyur, Karnataka, India*

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Brinjal, Genotype screening, *Leucinodes*, Morphological, Biochemical, Tolerance

ABSTRACT

Host plant resistance is a crucial strategy in reducing pesticide reliance, particularly for brinjal (*Solanum melongena* L.) crop. This study was conducted to evaluate the response of twelve commercially significant brinjal varieties to the shoot and fruit borer, *Leucinodes orbonalis* Guenee, at the Agricultural and Horticultural Research Station, Bavikere, Shivamogga, India during the summer (March-July) of 2023. Genotype Dhruva demonstrated notable pest tolerance, with the lowest recorded shoot damage (8.45%) and fruit damage (25.42%), alongside the highest marketable yield (15.67 MT ha $^{-1}$). In contrast, Harsha exhibited high susceptibility, displaying the highest shoot damage (17.60%) and fruit damage (55.23%), coupled with the lowest marketable yield (8.09 MT ha $^{-1}$). Morphological and biochemical analyses aimed to identify resistance sources revealed significant correlations. Shoot thickness correlated positively (r = 0.82) with shoot damage, while leaf trichome density showed a negative correlation (r=-0.96). Biochemical analyses indicated negative correlations of total phenols (r = -0.93) and tannins (r = -0.88) with fruit damage, while total sugars (r = 0.84) and total chlorophyll (r = 0.89) correlated positively with fruit damage and shoot damage, respectively.

INTRODUCTION

Eggplant, scientifically known as *Solanum melongena* Linn. and commonly referred to as brinjal, aubergine or guinea squash, is a highly favoured vegetable often hailed as the King of Vegetables. Belonging to the nightshade family Solanaceae, it thrives in diverse agro-climatic conditions, particularly in tropical and subtropical environments, with its origin traced back to the Indian subcontinent (Omprakash and Raju, 2014). In India, brinjal cultivation covers approximately 0.743 million hectares of agricultural land, yielding about 12.77 million tonnes per year, with a productivity of nearly 17.17 MT ha^{-1} (Indiastat, 2022). In Karnataka alone, brinjal cultivation spans over 0.10 lakh hectares, producing 1.15 lakh tonnes with a productivity of 11636 kg ha^{-1} (DES, 2022-23).

However, due to its year-round availability, brinjal crops are vulnerable to a range of biotic and abiotic stressors, with insect pests posing a significant threat. The brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee (Crambidae: Lepidoptera), is one of the most detrimental pests, inflicting considerable damage to the crop (Abhishek and Dwivedi, 2021; Nandi *et al*., 2017). Female moths lay their eggs on young leaves or tender shoots, and the emerging larvae burrow into these plant parts, leading to symptoms such as wilting, damage to shoots, flower drop, and fruit infestation. The damage inflicted by these borers can lead to yield losses of up to 60-80% and, in severe cases, complete crop destruction if left uncontrolled (Thakare *et al*., 2021).

Currently, conventional management practices rely heavily on frequent applications of chemical pesticides, leading to pesticide misuse, resistance, increased production costs, residues and adverse effects on both natural ecosystems and health of consumers (Sharma *et al*., 2019; Begum *et al*., 2017). Therefore, it is crucial to investigate alternative, ecofriendly methods for managing *L. orbonalis* infestations.

* Corresponding author: sarvadaman2000@gmail.com
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Host plant resistance (HPR) stands as an economically viable technique for effective pest management (Nagappan *et al*., 2017). The utilization of locally resistant cultivars emerges as a productive and cost-effective strategy in managing this pest while ensuring environmental safety. Hence, the present study aims to evaluate various commercially prevalent brinjal genotypes for their resistance to *L. orbonalis* infestation on both shoots and fruits and will also focus on identifying the antixenosis and antibiosis mechanisms that underpin resistance to *L. orbonalis* in these genotypes.

MATERIALS AND METHODS

A structured field experiment with Randomized Complete Block Design (RCBD) having 12 treatments and 3 replications was laid out to screen twelve commercial ruling brinjal genotypes *viz.,* Dhruva, Lalita, Udupi Gulla, MEBH-9, Sarpan-50, Sarpan-55, Sapran-65, Sarpan-25, Ankur Panna, Ruchika, Ajeet Virat and Harsha for their reaction against *L. orbonalis* infestation at Agricultural and Horticultural Research Station (AHRS), Bavikere (13°42'31.2"N 75°48'57.1"E) during Summer (March to July) 2023. Healthy brinjal seedlings of thirty days old, grown in a nursery, were transplanted into the main field in the month of april with a spacing of 90 cm × 60 cm in plots of 3 m × 3 m. The crop was managed according to the recommended practices, except for the plant protection schedule for managing *L. orbonalis*. However, while pesticide spray such as flonicamid 50 WG was used to manage sucking pests when the pest load was high, no sprays were applied to control the shoot and fruit borer or plant diseases. Following transplantation, a field screening of the genotypes was conducted to assess their susceptibility under natural infestation conditions.

Shoot damage

The per cent shoot damage of individual genotypes was recorded fortnightly starting from thirty days after transplanting till harvest and is represented as pooled mean per cent shoot damage of six observations. The mean percentage of shoot damage of each genotype was worked out using the formula suggested by Thakare *et al*. (2021).

Fruit damage

A total of three pickings were done in the season and the mean percentage of fruit damage was assessed at each picking and represented as pooled mean per cent fruit damage of three pickings. The mean percentage of fruit damage was computed using the formula suggested by Iesa (2021).

Marketable yield

The marketable yield was harvested totally thrice in the season and was determined by aggregating the yield of healthy fruits obtained from each individual picking and represented as total marketable yield of three pickings. Later, marketable plot yield was converted into kilogram per hectares using the formula suggested by Sheojat *et al*. (2022). The yield (kg ha^{-1}) was then converted to metric tonnes ha^{-1} by dividing the mass/area value by 1000.

Categorization

A categorization system to evaluate the response of genotypes to fruit damage by *L. orbonalis* described by Shigaonkar *et al*. (2022) was adapted for estimating relative resistance/susceptibility.

Morphological and biochemical characteristics

Furthermore, morphological and biochemical analyses were conducted on leaf and fruit samples collected at the peak fruiting stage to elucidate the source of resistance in brinjal genotypes against *L. orbonalis* infestation.

Morphological characteristics, including shoot thickness (cm), leaf trichome density and fruit colour and shape, were examined at peak fruiting stage to identify potential sources of resistance. Shoot thickness was measured 2.5 cm below the tip of five randomly selected shoots from each genotype, and the average girth was calculated using a manual vernier caliper. Trichome density was determined following the methodology outlined by Dash *et al*. (2021). Fruit colour and shape were visually recorded at the marketable maturity stage for each genotype.

Biochemical analyses were conducted on fruit samples collected at the marketable stage. Total phenols were measured using the Folin-Ciocalteu reagent protocol as described by Malik and Singh (1980). Total sugars were quantified by anthrone reagent method outlined by Sadasivam and Manickam (1992). Tannin content was assessed using the Folin-Denis method, according to Schanderl (1970). Chlorophyll content in leaf samples was determined using the acetone method outlined by Arnon (1949).

Statistical analysis

The data pertaining to shoot and fruit infestation underwent an arc sine transformation before statistical analysis. The yield data was analysed directly. The collected field experiment data were subjected to analysis of variance (ANOVA) and F-test, in accordance with the requirements of the RCBD. Similarly, the biochemical and morphological data were subjected for completely randomized design (CRD) without any transformation.

The means have been separated and compared through CD and Duncan multiple range test (DMRT) as per Gomez and Gomez (1984). The correlation between shoot, fruit damage by *L. orbonalis* and various morphological and biochemical characteristics was assessed using Pearson's correlation coefficient in R software and the results were visualized in a heatmap format to illustrate the relationships. The data recorded during the course of investigation, were also analysed with the help of computer software "OPSTAT" developed by Sheoran *et al*. (1998).

RESULTS AND DISCUSSION

Shoot damage

The shoot damage in brinjal genotypes was characterized by drooping and drying of terminal shoots and a characteristic entry hole was observed at the junction of two shoots (Fig. 1). Shoot damage in brinjal genotypes (Table I), attributed to *L. orbonalis* larvae boring activity, exhibited temporal trends with a peak at 60 days after transplanting during the flowering stage, subsequently declining in peak fruiting stage. The genotypic responses varied, indicating natural resistance mechanisms such as the presence of various morphological and biochemical characteristics (Table II). Tolerant genotype Dhruva with least percent shoot damage (8.45) had thinner shoots (0.73 cm) compared to susceptible and highly susceptible genotypes. In the genotypes characterized by greater shoot thickness, once the larvae of *L. orbonalis* enter the shoot, greater shoot thickness provides a larger internal space and more shoot contents for the larvae to feed upon. This facilitates extended feeding and boring activities, allowing the larvae to continue feeding and tunnelling down the shoot, which results in increased damage. Conversely, shoots with reduced thickness are advantageous as they restrict the space and resources available to the larvae, thereby mitigating the extent of shoot damage, as observed in the tolerant genotype Dhruva. Thus, thicker shoots are more susceptible to shoot borer attacks, consistent with findings by Shaukat *et al*. (2018), who reported that resistant genotypes typically exhibit thinner shoots compared to their susceptible counterparts. Additionally, leaf trichome density was negatively correlated with shoot damage (Fig. 2), serving as a protective barrier for tolerant genotype like Dhruva. Higher leaf trichome density, as seen in Dhruva (100.91/0.25 cm^2), impedes the movement of newly hatched larvae, making it more challenging for them to traverse the dense trichome layer and reach the shoot, which serves as the primary feeding site. Consequently, this physical barrier results in reduced shoot damage. This aligns with existing literature, particularly the work of Niranjana *et al*. (2016), confirming that densely trichome-covered leaves serve as a formidable barrier for newly emerged larvae. In case of chlorophyll content, the tolerant genotype Dhruva exhibited lower levels of chlorophyll (0.687 mg/g) compared to highly susceptible genotypes. Higher chlorophyll content seems to produce more lush green leaves, which likely attract female *L. orbonalis* moths for oviposition, resulting in a higher number of larvae per plant and increased shoot damage. In contrast, the darker green leaves of Dhruva appear less attractive to the moths, leading to reduced oviposition and fewer larvae, which reflects its lower susceptibility to infestation, in agreement with previous findings by Kumar *et al*. (2017).

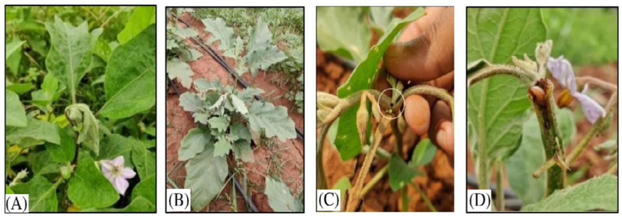

Fig. 1. Brinjal shoot damage by *L. orbonalis*; (A) and (B) Drooping of terminal shoot, (C) entry hole of larva and (D) larva boring into shoot.

Table I. Shoot and fruit damage (mean %) along with total marketable yield as influenced by *L. orbonalis* damage in brinjal genotypes.

Treatments (Genotypes)	Shoot damage (%)*	Fruit damage (%)**	Yield (MT ha^{-1})***
T_1 Dhruva	8.45 (16.88)^e	25.42 (30.28)^e	15.67 ^{a}
T_2 Lalita	11.19 (19.54)^{cd}	34.92 (36.21)^{cde}	13.78 ^{abc}
T_3Udupi Gulla	9.84 (18.28)^{de}	31.47 (34.08)^{de}	14.90 ^{ab}
T_4 MEBH- 9	15.61 (23.27)^{ab}	50.26 (45.15)^{ab}	8.48 ^{g}
T_5 Sarpan -50	13.44 (21.49)^{bc}	45.03 (42.15)^{abc}	10.83 ^{ef}
T_6 Sarpan-55	10.13 (18.53)^{de}	38.21 (38.17)^{bcd}	13.30 ^{bcd}
T_7 Sarpan-65	11.65 (19.95)^{cd}	41.18 (39.92)^{abcd}	12.43 ^{cde}
T_8 Sarpan-25	12.91 (21.06)^c	42.88 (40.89)^{abcd}	11.70 ^{de}
T_9 Ankur Panna	16.12 (23.67)^a	50.75 (45.43)^{ab}	8.73 ^{g}
T_{10} Ruchika	16.16 (23.69)^a	48.20 (43.97)^{ab}	9.10 ^{fg}
T_{11} Ajeet Virat	17.30 (24.56)^a	49.51(44.72)^{ab}	8.21 ^{g}
T_{12} Harsha	17.60 (24.78)^a	55.23 (48.24)^a	8.09 ^{g}
S.Em(±)	0.67	2.30	1.19
C.D. @ 5%	1.98	6.76	3.50
CV(%)	8.76	9.39	14.11

Figures in parentheses are arc sine transformed values. Means followed by the same letter do not differ significantly by DMRT (P= 0.05). Note: *Pooled mean shoot damage of six observations ** Pooled mean fruit damage of three pickings. ***Pooled marketable yield of three pickings.

Table II. Biochemical and morphological characteristics of brinjal genotypes.

Treatments (Genotypes)	Biochemical and morphological parameters							
	Total phenols (mg/g)	Tannins (mg/g)	Total sugars (mg/g)	Total chlorophyll (mg/g)	Shoot thickness (cm)	Leaf trichome density (no./0.25cm²)	Colour of the fruit	Shape of the fruit
T_1 Dhruva	4.08	6.09	5.21	0.687	0.73	100.91	Purple white striped	Oval
T_2 Lalita	3.03	4.84	8.27	0.698	0.83	86.51	Purple white striped	Oval
T_3Udupi Gulla	3.32	5.46	7.13	0.735	0.91	92.70	Green variegated	Spherical
T_4 MEBH- 9	1.80	2.96	15.35	0.845	1.76	49.83	Green	Long
T_5 Sarpan -50	2.17	1.40	16.94	0.793	1.67	66.26	Green striped	Oblong
T_6 Sarpan-55	3.54	4.21	10.47	0.732	1.13	81.40	Purple white striped	High round
T_7 Sarpan-65	2.72	3.90	17.96	0.768	1.29	78.58	Purple white striped	Oblong
T_8 Sarpan-25	2.02	1.71	11.54	0.862	2.26	72.81	Glossy green striped	High round
T_9 Ankur Panna	1.63	1.08	13.16	0.787	1.41	46.13	Green variegated	Oval
T_{10} Ruchika	2.45	2.33	13.59	0.884	1.96	59.46	Purple white striped	High round
T_{11} Ajeet Virat	1.83	3.27	15.67	0.916	2.14	54.51	Purple white striped	Oval
T_{12} Harsha	1.58	0.77	18.58	0.942	2.32	39.93	Green variegated	Oval
S.Em(±)	0.14	0.25	0.75	0.04	0.26	2.75	-	-
C.D. @ 5%	0.42	0.75	2.19	0.13	0.09	8.02	-	-

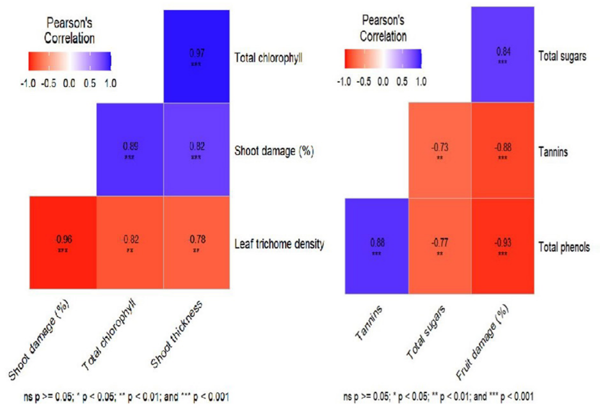

Fig. 2. Correlation of shoot and fruit damage by *L. orbonalis* with morphological and biochemical characteristics.

Fruit damage

Unlike damage to shoots which got to decline with advancement of season or crop growth, the fruit damage remained persistent and was maximum at third picking. This indicates the preference of the pest towards fruiting structures. The genotype Dhruva exhibited the lowest fruit damage of 25.42 percent (Table I) indicating a level of resistance or tolerance to *L. orbobalis* attack. This resilience was attributed to biochemical characteristics, specifically the high phenol and tannin content in Dhruva's fruits, acting as antifeedants and the low sugar content making it less favourable for pest feeding. The tolerant genotype Dhruva, characterized by higher phenol content of 4.08 mg/g, recorded the least fruit damage because the larvae of *L. orbonalis* is deterred by the presence of phenols, as they can disrupt the insects' physiological processes and deter feeding. This makes it less likely for the borer to lay eggs on or consume the fruit, consistent with findings by Nagappan and Vethamoni (2016). Furthermore, the high tannin content (6.09 mg/g) in Dhruva contributed to a reduced percentage of fruit damage. Elevated tannin levels in brinjal fruits likely deter *L. orbonalis* larvae through mechanisms such as decreased protein digestibility, toxicological effects and feeding deterrence, making Dhruva's fruits less palatable to the pest. Additionally, highly susceptible genotypes recorded high sugar content (5.21 mg/g) which served as a more nutritionally dense and energy-rich food source for borers, leading to increased growth and reproduction rates among the borers, attributed to their increased capacity to extract energy from the sugary fruits, resulting in increased fruit damage. This aligns with previous reports by Elanchezhyan *et al.* (2008). The influence of fruit colour and shape on pest damage was also investigated across various brinjal genotypes. In terms of colour, no significant relationship was found between fruit colour and the level of infestation by *L. orbonalis.* The tolerant genotype Dhruva with least fruit damage, also the susceptible genotypes Lalita and Sarpan-55 and the highly susceptible genotypes Sarpan-65, Ruchika and Ajeet Virat, were all purple white striped indicating no correlation (Fig. 3). Similarly, fruit shape showed no significant impact on the infestation level by *L. orbonalis*. The tolerant genotype Dhruva, the susceptible genotype Lalita and the highly susceptible genotypes Ajeet Virat, Ankur Panna and Harsha were all oval in shape, indicating no correlation between shape of the fruit and level of infestation by *L. orbonalis*. These results are consistent with previous studies by Naqvi *et al*. (2009), which indicate that fruit colour and shape do not significantly influence the preference of the fruit borer, *L. orbonalis*.

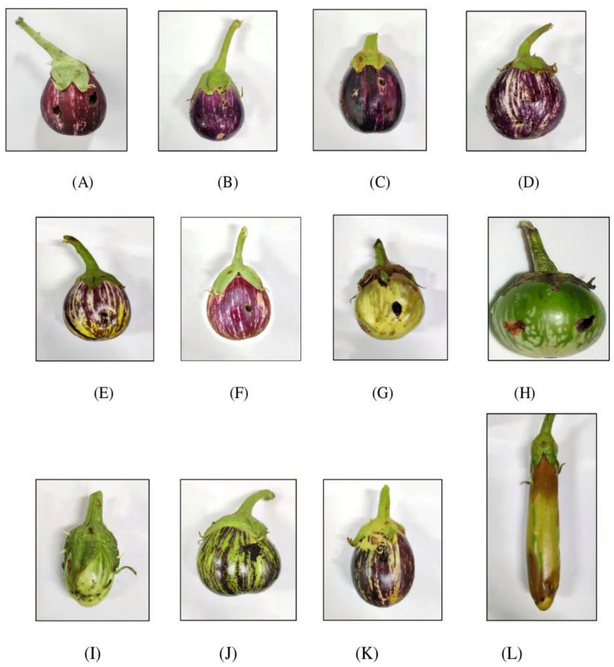

Fig. 3. Fruit damage by *L. orbonalis* in (A) Ajeet Virat, (B) Dhruva, (C) Sarpan- 55, (D) Sarpan- 65, (E) Lalita and (F) Ruchika (G) Harsha, (H) Udupi Gulla, (I) Ankur Panna (J) Sarpan-50, (K) Sarpan-25 and (L) MEBH-9 brinjal genotypes.

On the basis of mean percentage of fruit damage, none of the genotypes screened exhibited immunity, high resistance or fair resistance (Table III). These findings align with Elanchezhyan *et al*. (2008), who found that none of the 25 brinjal varieties tested showed immunity to *L. orbonalis* attacks.

Marketable yield

The maximum marketable yield was obtained from the tolerant genotype Dhruva (15.67 MT ha^{-1}), attributed to its minimal shoot and fruit damage, resulting in superior yield and Harsha (8.09 MT ha^{-1}) recorded lowest yield with high shoot and fruit damage percentages (Table I). These findings align with Chakraborty *et al*. (2023), who reported the highest fruit yield (19.46 MT ha^{-1}) in the germplasm Shingnath, exhibiting significantly low fruit damage (17.34%). Conversely, the highly susceptible germplasm Tripura Brinjal 18 recorded the lowest yield of 5.47 MT ha^{-1}. Dahatonde *et al*. (2019) also noted similar trends, with AB-8/5 recording the highest yield (21.42 q ha^{-1}) and the least fruit damage at 14.60 %. Conversely, JBJL-10/203, with a fruit damage of 29.19 %, exhibited the lowest yield of 8.01 q ha^{-1}.

CONCLUSION

It can be inferred that none of the twelve commercially significant brinjal genotypes achieved complete immunity to *L. orbonalis*. However, the genotype Dhruva showed notable tolerance with higher yield and less damage. Reduced shoot damage was associated with thinner shoots and higher leaf trichome density. Fruit shape and colour did not significantly impact infestation levels. Genotypes with higher total phenols and tannins, like Dhruva, had less fruit damage, while higher sugar content correlated with more damage, and higher chlorophyll levels were linked to greater shoot damage. These findings suggest that breeding programs should focus on traits like reduced

Table III. Categorization of brinjal genotypes based on fruit infestation (Shigaonkar *et al*., 2022).

Categorization			
Fruit infestation (%)	**Reaction**	**Genotypes**	**No. of genotypes**
0	Immune	-	
1-10	Highly resistant	-	
11-20	Fairly resistant	-	
21-30	Tolerant	Dhruva	1
31-40	Susceptible	Lalita, Udupi Gulla, Sarpan-55,	3
Above 40	Highly susceptible	MEBH-9, Sarpan-50, Sapran-65, Sarpan-25, Ankur Panna, Ruchika, Ajeet Virat, Harsha	8

shoot thickness, high leaf trichome density, and elevated phenol and tannin levels to develop brinjal cultivars with better productivity and lower damage from *L. orbonalis*.

DECLARATIONS

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Statement of conflict of interest

The authors have declared no conflict of interest.

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