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Research Article

Biochemical Basis of Resistance in Brinjal Genotypes Against Shoot and Fruit Borer (*Leucinodes Orbonalis*, Guenee)

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Abstract

The biochemical basis of host plant resistance for shoot and fruit borer of brinjal was investigated, using two brinjal hybrids and ten cultivated varieties reflected different levels of infestation. The different levels of biochemical constituents namely total phenol and total sugar were observed that exhibited a clear correlation with the pest incidence. A higher level of total phenol activity was observed in resistant Brinjal-85 and Local long. Shalimar Brinjal Hybrid-1 and 2, showed maximum shoot infestation of 9.10, 8.69 and fruit infestation of 23.07 and 22.0 per cent, respectively, recorded higher content of total sugars and lower content of total phenols, respectively. Brinjal Oblong and Brinjal Purple Long exhibited shoot and fruit infestation of 7.50, 18.18 and 7.50, 16.63 per cent recorded the total phenol content of 1.16, 1.31 and 0.78, 0.83 mg/g in shoots and fruits, respectively. Varieties, Brinjal -85 and Local Long were found least attacked by the pest recorded the shoot and fruit damage of 2.34, 4.60 and 3.30,5.15 per cent, respectively with total phenol of 2.30, 2.09 and 1.51,1.45mg/g in shoots and fruits, respectively. The Correlation coefficients of shoot and fruit infestation were strong and negative with total phenols and positive and significant with respect to total sugars.

Keywords: Biochemical, Resistance, Brinjal, *Leucinodes Orbonalis*

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Introduction

Brinjal (*Solanum melongena* L.) is an important solanaceous vegetable, which holds a coveted position among different vegetables. Due to its low calorific value (24 kcal 100 g-1) and high potassium content (200 mg 100 g-1), it is suitable for diabetes, hypertensive and obese patients. It holds an important place in China, India, Japan and Europe. It is believed to be native of tropics of the old world [1]. India seems to be original habitat as this plant still exists here in wild state [2]. India is the second largest producer of brinjal crop after China, and in India it is popular vegetable grown [3]. In India it is cultivated in an area of 0.612 million hacters with production of 105.63 million tons and average productivity is 17.2 metric tons per hectare [4]; making it one of the main sources of cash for many farmers [5].While among the states, area under this crop in Jammu and Kashmir is 850 hacters with the production of 17000 metric tons and productivity of 20 metric tons per hector [6]. Among the biotic stress factors that hamper the production of brinjal, brinjal shoot and fruit borer (BSFB) (*Leucinodes orbonalis* Guen.) is the most destructive [6,7], and economically harmful insect pests of brinjal [8,9,10]. *L. orbonalis* is practically monophagous, feeding principally on eggplant [11]. The loss caused by this deleterious pest was reported to be around 54 to 60% [12], 12.59 to 38.65 [13], 60-70% [14], 40.96% [15] and 70 to 80% [16] and has become a major threat for brinjal cultivation. Besides it inflicts sizeable damage up to80 % to vitamin C [10]. Dar *et al.* [17] conducted an evaluation of combined options for the management of *L. orbonalis*, but the chemical control of shoot and fruit borer may reduce the pest attack to a greater extent; however, it causes adverse effects on the environment and human health, besides the indiscriminate use makes it expedient to seek for safe and eco-friendly measures [18]. Before initiating any breeding programme, one must have enough information about the ways and means by which the resistance can be exploited. Besides, the various morphological characteristic of the brinjal varieties/ genotypes responsible for resistance to *L. orbonalis* [19], biochemical defense mechanism would certainly be helpful in the selection of plants as a source of host plant resistance [20,21]. Exploiting host plant resistance through breeding approaches will be highly beneficial to develop superior high yielding genotypes with resistance to the shoot and fruit borer in brinjal. Among the major constraints in economic cultivation of brinjal, pest infestation causes heavy losses. Chemical control is widely used means of managing insect pests in brinjal. Repeated uses of broad spectrum synthetic chemicals also result in environmental contamination, bioaccumulation and biomagnifications of toxic residues and disturbance in ecological balance [22]. Hence, there is an urgent need to look alternate and safer method. *Bt.* transgenic technology has offered promise of sustainable management of BSFB in brinjal [23,24]. However,presently there is an indefinite moratorium on the commercial cultivation of *Bt.* brinjal. Therefore, it is important to systematically screen the brinjal germplasm on the biochemical basis for possible sources of genetic resistance against BSFB. Many reports and reviews claim that some of the cultivated accessions of *S. melongena* possess resistance to BSFB [25]. A suggestion was made that selecting genotypes with higher glycoalkaloid (solasodine) content, total phenols and polyphenol oxidase activity would help improve resistance to BSFB infestation without affecting the yield potential [21,26]. Protein (r = 0.48), sugars (r = 0.65) and moisture content (r = 0.97) of fruits showed significant positive correlation, while phenols (r = -0.89), flavonols (r = -0.83), dietary fibre (r = -0.92), ash (r = -0.83) and starch (r = -0.88) contents showed significantly negative correlation with per cent fruit infestation (Prasad *et al.*, 2014). Dar *et al*, [20] conducted the path-analysis (corr. x, corr. y) and observed that crude fibre, ash, lignin and moisture content of brinjal had -1,-0.82,-0.89 and +1 correlation with *L. orbonalis* infestation. There are reports which indicate that wild brinjal species containing higher polyphenols and phenols, e.g. *S. macrocarpon* are resistant to BSFB [27,11]. Generally, brinjal varieties vary in the resistance exhibition to *L. orbonalis* [17,28], but pulp and peel or skin of deep blue/purple varieties of brinjal has significant amounts of phenolic flavonoid phytochemical called anthocyanin which act as antioxidants and have potential health effects against cancer, aging, inflammation and neurological diseases [29].Total phenol content and polyphenol oxidase enzyme activity, havean immense importance in controlling the degree of browning of fruit pulp due to the effect of digenic interactions [30].Therefore current study were done to evaluate different phagostimulant or deterrent biochemical constituents of brinjal collections which are linked with resistant or susceptibility against *L.orbonalis*.

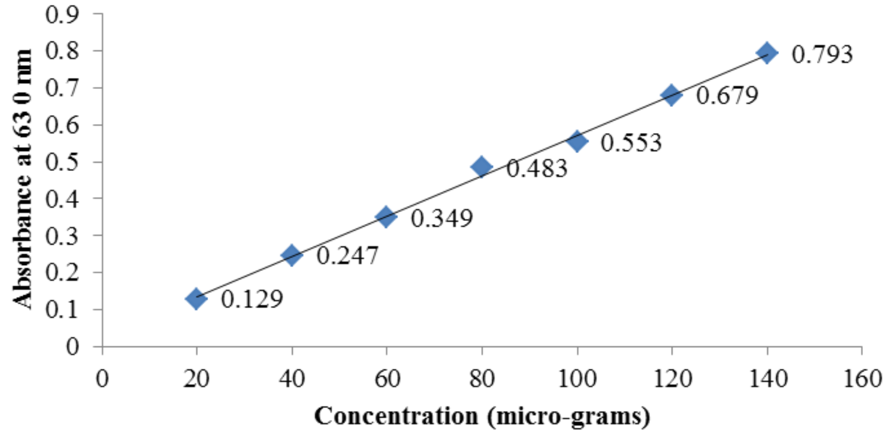
Materials and Methods

A field experiment was conducted in a randomized block design (RABD) with three replications and twelve treatments in an area of 500 m^2. The accessions of 12 brinjal varieties/genotypes screened against brinjal shoot and fruit borer (*Leucinodes orbonalis* Guenee). Thirty-day old seedlings were transplanted with plant to plant and row to row spacing of 60 x 45 cm during May to June 2011-12 in the weather condition of 24 ±5C^0 and 62 ± 4 per cent RH at Sher-e-Kashmir University of Agricultural Science and Technology, Kashmir. The cultural practices except plant protection measures were followed as per the crop production guide for horticultural crops. They seedlings were planted by maintaining fifteen plants per plot of size 13.20m^2 per replication and a total of 45 plants per entry. Five plants per replication were tagged at random and observed for the incidence of shoot and fruit borer at weekly interval starting from fifteenth day after transplanting (DAT) to harvest. After each observation, the damaged shoots were removed. Similarly, in case of fruit infestation, number and weight of healthy and damaged fruits were recorded and per cent damage was calculated. Based on per cent fruit infestation genotypes were screened and rated following the range given by Mishra *et al*. [31]. Similarly, the genotypes were also screened based on per cent susceptibility by Ali *et al*. [32].The percentage data obtained from the field experiment were subjected to arcsine (angular) transformation [33]. Biochemical contents and incidence of pests were correlated by simple analysis using O.P Shereom packages, S.P.S.S and Minitab. Total phenols estimated from fruit samples at 45, 70 DAT and shoots at 15, 45 DAT by Folin-Ciocalteu reagent method.While as, Soluble sugar were estimated in shoots at 15, 45 and in fruits at 45, 70 DATby Anthrone method [34].

Phenols

Sample of shoot and fruit each weighing 0.5 g was taken and grinded with the help of pestle and mortar along with 10 ml of 80% ethanol. Later sample were centrifuged and homogenated at 10, 000 rpm for 20 minutes. Supernatant were saved and residues re-extracted with 5 times volume of 80% ethanol. Samples were centrifuged again at 10, 000 rpm and the supernatants were pooled and later evaporated to dryness then obtained and residue were dissolved in 5ml of distilled water. Aliquots of (0.2 to 2) were pipette out into different test tubes each added by 0.5 ml of Folin-Ciocalteu Reagent (FCR). After 3 minutes, 2 ml of 20% Na_2CO_3 was added and mixed thoroughly. Then tubes were placed in boiling water for exactly 1 minute and pooled. Absorbance was measured in spectrophotometer at 650 nm against reagent blank. Finally standard curve using different concentrations of catechol were prepared. From the standard curve concentration of phenols in the test sample were estimated and expressed as mg of phenols per gram of sample material. Standard graph was drawn by plotting concentration of standard on the X-axis *vs* absorbance on Y-axis (**Figure 1**). From the graph amount of total phenol present in the sample were calculated as.

$$\text{Phenols (mg/g)} = \frac{\text{Micro liters from stand curve x volume x dilution}}{\text{Weight of sample x 1000}}$$



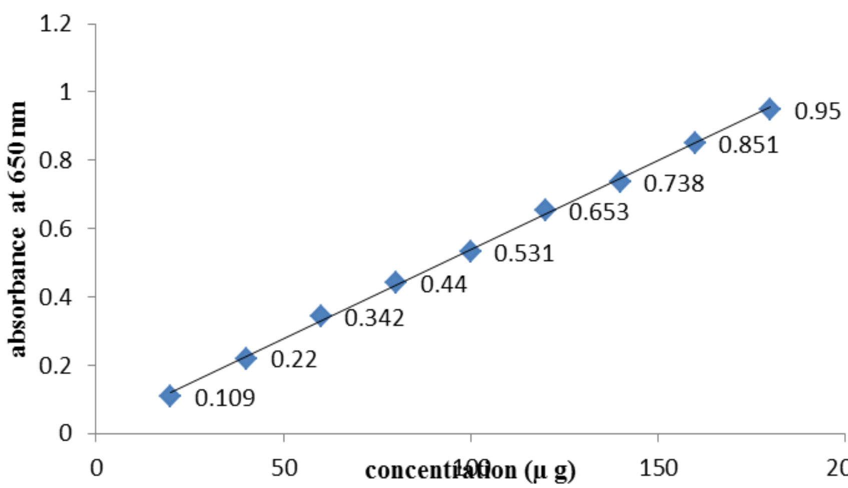
Regression equation: Y= 0.015+0.005 X: R^2 = 0.977

Figure 1 Standard curve for the estimation of phenols in brinjal: Standard curve for phenols estimated (absorbance vs concentration) by Folin-Ciocalteu reagent method as given by Bray and Thrope (1954

Total sugars

100 mg of the sample (shoot and fruit) were taken and hydrolyzed in a boiling water bath for 3 hours with 5 ml of 2.5 HCl and cooled at room temperature. Then it was neutralized with solid sodium carbonate until the effervescence got ceased and the volume was made to 100 ml and centrifuged at 5000 rpm for 20 minutes. The supernatants were collected and 1 ml aliquots were taken for further analysis. Standards were prepared by taking the 0, 0.2, 0.4, 0.8 and 1ml of working standards while 0 served as blank. Volume was made to 1 ml in all the tubes including sample tube by adding distilled water. 4 ml of anthrone reagent was added to each tube and heated for 8 minutes in a boiling water bath. Then cooled rapidly and green to dark green colour were read in spectrophotometer at 630 nm. Standard graph was drawn by plotting concentration of standard on the X-axis *vs* absorbance on Y-axis (**Figure 2**). From the graph amount of total sugar present in the sample were calculated as.

$$\text{Total sugars (mg/g)} = \frac{\text{Sugar value from graph (µg)}}{\text{Aliquot sample used (1 ml)}} \times \frac{\text{Total volume of extract (ml)}}{\text{Weight of sample (mg)}} \times 100$$



Regression equation: Y=0.015+0.005X; R^2=0.997

Figure 2 Standard curve for the estimation of sugars in different brinjal genotypes during 2012. Standard curve for the estimation of sugars (optical density *vs* concentration) estimated by Anthrone method as given by Sadasivam and Manickam (1992).

Results and Discussion

Many biochemical factors are known to be associated with insect resistance and it is obvious that the biochemical factors are more important than morphological and physiological factors in conferring non-preference and antibiosis. Some biochemical constituents may act as feeding stimuli for insects. Occurrence at lower concentration or total absence of such biochemicals leads to insect resistance [35]. Biochemical factors of the host plant have been reported to play a vital role in resistance to various insect pests [36] and relatively resistant genotypes contained higher amount of phenols inherently [37] as these are often associated with the feeding deterrence, growth inhibition and in higher concentration could ward off insect pests because of the direct toxicity [38]. Preneetha [25] found that while selecting brinjal genotypes for shoot and fruit borer resistance, apart from their performance based on the yield, consideration may also be given on the quantity of biochemical constituents. However, in general various biochemical constituents present in plants showed a considerable level of resistance to insect pests [39] and in brinjal the low sugar content and higher phenolic compounds [40,41] offered a significant level of resistance to various biotic stresses.

In present investigations genotypes screened, Brinjal-85 (resistant) and Local Long (resistant) recorded lowest fruit infestation of 3.30 and 5.15 per cent; whereas, shoot infestation was 2.34 and 4.60 per cent, respectively, corresponding to the high level of total phenols both at initial and final stages of crop growth. In Brinjal-85 and Local Long total phenol content at initial stage of shoot was registered as 1.93, 1.61 and at final stage 2.30, 2.09 mg/g dry weight (**Table 1**). While as, in fruits total phenol content registered at initial and final stage was 1.41, 1.36 and 1.51, 1.45 mg/g dry weight, respectively. This finding is analogous to the observations made by Prasad *et al.* [21], Docimo *et al*. [42] change, Prabhu *et al*. [43] and Khorsheduzzaman *et al*. [27] who found that selection of genotypes with higher glycoalkaloid (solasodine), total phenols and polypheol oxidase activity improve resistance to shoot and fruit borer infestation. Shalimar Brinjal Hybrid-1 (highly susceptible) and Shalimar Brinjal Hybrid-2 (susceptible) recorded highest fruit infestation of 23.07 and 20.00 per cent (number basis) and shoot infestation of 9.10 and 7.70 per cent, respectively corresponding to low levels of total phenol content both at initial and final stages of growth, whereby in Shalimar Brinjal Hybrid-1 and Shalimar Brinjal Hybrid-2 total phenol content registered at initial and final stages of fruit was 0.58, 0.66 and 0.67, 0.72 mg/g dry weight. Whileas, in shoots phenol content at initial stage was recorded 0.73, 0.84 and at final stage 0.88, 0.98mg/g dry weight, respectively. This is in conformity with the findings of Prabhu *et al*. [43] who observed that total phenol content and its activity is higher in shoots as compared to fruits at all stages of growth. Also, the Phenol content is the one of the most important character to reduce the shoot and fruit borer incidence. If the phenol content is high borer infestation will be less [44].

Table 1 Total phenol content of shoots and fruits of different brinjal genotypes screened against shoot and fruit borer *(Leucinodes orbonalis* Guenee)

S. No.	Genotypes	Mean percentage fruit infestation (Number basis)	Mean total phenol content (mg/g) Shoots 15 DAT	45 DAT	Fruits 45 DAT	70 DAT
1.	Shalimar Brinjal long-217	14.28^{d} (22.07)	1.32^{c}±0.027	1.49^{d}±0.038	0.88^{b}±0.011	0.97^{d}±0.033
2.	Local long	5.15^{a} (12.71)	1.61^{e}±0.060	2.09^{h}±0.069	1.36^{d}±0.072	1.45^{g}±0.035
3.	Brinjal oblong	18.18^{e} (25.20)	0.98^{b}±0.027	1.16^{b}±0.029	0.72^{a}±0.065	0.78^{b}±0.015
4.	Pusa purple long	16.63^{e} (24.31)	1.19^{c}±0.055	1.31^{c}±0.044	0.78^{b}±0.049	0.83^{b}±0.014
5.	Shalimar Brinjalpurpe Long-42	11.11^{c} (18.90)	1.50^{d}±0.019	1.67^{e}±0.0072	1.10^{c}±0.056	1.21^{f}±0.059
6.	Shalimar Brinjal Hybrid-1	23.07^{g} (28.48)	0.73^{a}±0.020	0.88^{a}±0.030	0.58^{a}±0.006	0.67^{a}±0.023
7.	Shalimar Brinjal purple Round-8	8.33^{b} (16.70)	1.61^{e}±0.059	1.93^{g}±0.133	1.31^{d}±0.015	1.29^{f}±0.060
8.	Dilruba-2	16.60^{e} (24.19)	1.30^{c}±0.035	1.39^{c}±0.030	0.81^{b}±0.024	0.87^{c}±0.013
9.	Brinjal-85	3.30^{a} (11.92)	1.93^{f}±0.038	2.30^{i}±0.057	1.41^{d}±0.050	1.51^{g}±0.022
10.	Shalimar Brinjal long-208	12.50^{c} (19.43)	1.41^{d}±0.037	1.58^{d}±0.041	1.06^{c}±0.069	1.07^{e}±0.060
11.	Shalimar Brinjal Hybrid-2	20.00^{f} (26.06)	0.84^{a}±0.003	0.98^{a}±0.015	0.66^{a}±0.068	0.72^{a}±0.011
12.	Shalimar Brinjal purple Round-1	10.08^{b} (16.72)	1.54^{d}±0.021	1.81^{f}±0.098	1.20^{c}±0.001	1.24^{f}±0.060
	CD $_{(0.05)}$	**1.90**	**0.14**	**0.11**	**0.14**	**0.08**
	SE	**1.36**	**0.06**	**0.05**	**0.07**	**0.04**

15 DAT = Days after transplanting (15th July 2011); 45 DAT = 15th August 2011; 70 DAT = 10th September 2011

The present results indicated that phenols are important factors in conferring non-preference, antibiosis and exhibited a clear variation with the age of the crop (Fig 1) which is in agreement with Kaur *et al*. [45], Kalloo [46] and Prabhu *et al.* [43] who reported that phenols possessed the insect resistance properties and there is a clear variation in total phenolic content with age of the crop. The *S. torvum* with green color fruit were significantly less susceptible and violet color (pink) fruit of BARI Brinjal-1 was highly susceptible followed by light green color fruit of BARI Brinjal-6 fruit [47], the possible reason is the difference in the total phenol content. In addition to higher content of the phenol in green fruits white coloured fruits were found rich in flavonols therefore expressing resistance against the *L. orbonalis* [40]. In general, total phenol content increased with the age of the crop, and the genotypes with higher phenol content impart the resistance by having direct negative effect on *L.orbonalis* infestation [26]. The cultivars having higher total phenols in leaves supported fewer insect pests in brinjal [48]. A negative and significant correlation existed between phenols in shoots and fruits (**Table 2**) with infestation by *L.orbonalis* and is supported by Shinde [49] who found that phenols are negatively correlated with the borer damage and are responsible to impart resistance. Phenolic compounds are an important component of the oxidative defenses of plants against pests, when compounds become oxidized in midgut of insects and their reaction products are responsible for causing oxidative stress in the digestive tract producing reactive oxygen species (ROS) [50], such as semiquinone radicals, reduce the growth rate of leaf-feeding insects [51]. Phenolic compounds work by producing reactive oxygen species, specifically tannins get oxidized in the guts of insects and the oxidation products have the potential to damage vital nutrients causing either insect deterrence or antibiosis [52].

Table 2 Correlations among various biochemical characteristics of different brinjal genotypes in relation to susceptibility to shoot and fruit borer (*Leucinodes orbonalis* Guenee).

Mean percent fruit infestation (no. basis)	**Mean percent fruit infestation (wt. basis)**	**Mean percent shoot infestation**	**Sugars in fruit (45 DAT)**	**Sugars in fruit (70 DAT)**	**Sugar in shoot (15 DAT)**	**Sugar in shoot (45 DAT)**	**Phenol in fruit (45 DAT)**	**Phenol in fruit (70 DAT)**	**Phenol in shoot (15 DAT)**	**Phenol in shoot (45 DAT)**	**Moisture (%)**	**Ash (%)**
	X_2	**X_3**	**X_4**	**X_5**	**X_6**	**X_7**	**X_8**	**X_9**	**X_{10}**	**X_{11}**	**X_{12}**	**X_{13}**
X_1	0.992**	0.973**	0.978**	0.971**	0.972**	0.981**	-0.985**	-0.988**	-0.963**	-0.963**	0.98**	-0.954**
X_2		0.951**	0.975**	0.965**	0.964**	0.981**	-0.98**	-0.981**	-0.966**	-0.993**	0.986**	-0.951**
X_3			0.979**	0.976**	0.98**	0.967**	-0.975**	-0.973**	-0.956**	-0.972**	0.957**	-0.957**
X_4				0.997**	0.995**	0.995**	-0.983**	-0.977**	-0.981**	-0.992**	0.97**	-0.982**
X_5					0.995**	0.995**	-0.972**	-0.967**	-0.979**	-0.985**	0.963**	-0.986**
X_6						0.987**	-0.971**	-0.96**	-0.981**	-0.984**	0.959**	-0.987**
X_7							-0.976**	-0.976**	-0.977**	-0.993**	0.978**	-0.981**
X_8								0.992**	-0.954**	-0.955**	0.898*	-0.938**
X_9									-0.949**	-0.884*	0.891*	-0.932**
X_{10}										-0.876*	0.865*	-0.977**
X_{11}											0.875*	-0.97**
X_{12}												-0.94**

**Significant at 1 per cent *Significant at 5 per cent

In present investigations Brinjal-85 (resistant) and Local Long (resistant) recorded lowest fruit and shoot infestation corresponding to the low levels of total sugars both at initial and final stages of crop growth as in Brinjal-85 and Local Long total sugar content at initial stage of fruit was registered as 5.59, 6.16 and at final stage 5.87, 6.22mg/g dry weight (**Table 3** and Figure 2). Whileas, in shoots total sugar content at initial stage was registered 5.45, 5.80 and at final stage 3.03, 3.36 mg/g dry weight, respectively. The results are in agreement with Khorsheduzzaman *et al*. [27], Isahaque and Chaudhuri [53] and Panda and Das [54] who found that susceptible genotypes contain higher content of total sugars as compared to resistant ones. Genotypes *viz*., Brinjal-85 and Local Long provided less feeding stimulus to borers due to high phenols and low total soluble sugars, thus could be utilized in the breeding programme for the development of shoot and fruit borer resistant varieties in brinjal. Total sugar content in susceptible cultivars were found ranged from 0.53-24.77 % in 2012 to 0.71-20.36 % in 2013 [40].These results are in agreement with Lapidus *et al*. [55]; Knapp *et al*. [56]; Kalode and Pant [57]; Jat and Pareek [58] and Khorsheduzzaman *et al*. [27]

who found that in brinjal, sugar content acted as a feeding stimulant to the borers. Also, the highest sugars content (1.76 g/100 g FW) was recorded in highly susceptible accession, IC090093 (72% infestation) [59], while lowest (0.75 g/100 g FW) was recorded in resistant accession, IC280954 (7.89% infestation) Prasad *et al.* [21].

Table 3 Total sugar content of shoots and fruits of different brinjal varieties/genotypes screened against shoot and fruit borer *(Leucinodes orbonalis* Guenee)

S. No.	Genotypes	Mean shoot infestation (per cent)	Total sugar content (mg/g) Shoots		Mean fruit in festation on nu mber basis (%)	Total sugar content (mg/g) Fruits	
			15 DAT	45 DAT		45 DAT	70 DAT
1	Shalimar Brinjal Long-217	6.70e (14.55)	8.08^{c}±0.427	6.00f 0.012	14.28^{e}(22.07)	9.37^{d}±0.404	9.44^{c}±0.164
2	Local Long	4.60^{b} (12.62)	5.80a±0.498	3.36^{b}±0.018	5.15 ^{b}(12.71)	6.16^{a}±0.402	6.22^{a}±0.408
3	Brinjal Oblong	7.50^{f} (15.88)	9.59^{d}±0.347	8.24^{i}±0.085	18.18^{f} (25.20)	11.49^{e}±0.578	12.51^{e}±0.691
4	Brinjal Purple Long	7.50^{f} (15.88)	8.91^{d}±0.500	7.36^{h}±0.137	16.63^{f} (24.31)	10.80^{e}±0.564	11.36^{d}±0.394
5	Shalimar Brinjal Purple Long-42	5.34^{c} (13.34)	7.17^{b}±0.587	5.24^{e}±0.088	11.11^{d} (18.90)	7.99^{c}±0.184	8.14^{b}±0.327
6	Shalimar Brinjal Hybrid-1	9.10^{g} (17.53)	11.47^{f}±0.826	9.50^{j}±0.116	23.07^{h} (28.48)	13.18^{i}±0.252	14.63^{f}±0.669
7	Shalimar Brinjal Purple Round-8	4.96^{b} (12.82)	6.07^{a}±0.452	4.05^{c}±0.135	8.33^{c} (16.70)	6.64^{b}±0.355	6.82^{a}±0.366
8	Dilruba-2	6.97^{e} (15.75)	8.28^{c}±0.520	6.86^{g}±0.067	16.60^{f} (24.19)	9.73^{d}±0.345	10.47^{c}±0.130
9	Brinjal-85	2.34^{a} (6.91)	5.45^{a}±0.348	3.03^{a}±0.120	3.30^{a} (11.92)	5.59^{a}±0.309	5.87^{a}±0.489
10	Shalimar Brinjal Long-208	6.20^{d} (14.37)	7.50^{c}±0.551	5.96^{f}±0.015	12.50^{d} (19.43)	8.60^{c}±0.271	9.13^{b}±0.296
11	Shalimar Brinjal Hybrid-2	7.70^{f} (16.08)	10.53^{e}±0.751	9.47^{j}±0.176	20.00^{g} (26.06)	12.73^{f}±0.113	14.06^{f}±0.393
12	Shalimar Brinjal Purple Round-1	5.10^{c} (13.02)	6.41^{b}±0.438	4.86^{d}±0.042	10.08^{c} (16.72)	7.19^{b}±0.170	7.41^{b}±0.301
	CD $_{(P= 0.05)}$	**0.37**	**0.78**	**0.29**	**1.77**	**0.71**	**1.03**

15 DAT = Days after transplanting (15th July 2011); 45 DAT = 15th August 2011; 70 DAT = 10th September 2011

Total sugar content in fruits was comparatively higher as compared to the shoots and is supported by results of Panda and Das [54] who found that higher sugar content is present in brinjal fruits as compared to shoots which acted as feeding stimulant for borers. Lower levels of total sugars were found in genotypes which are fairly resistant and resistant to the *L.orbonalis* infestation. Fairly resistant genotypes *viz*., Shalimar Brinjal Purple Round-8 and Shalimar Brinjal Purple Round-1 suffered the infestation of 8.33 and 10.08 per cent on number basis and were found to have total sugar content of 6.07, 6.41 and 4.05, 4.86 mg/g dry weight both at initial and final stages of shoot growth, respectively. Whileas, in fruits total sugar content was comparatively higher ranging from 6.64 to 7.19 and 6.82 to 7.41mg/g dry weight at initial and final stages of fruit growth, respectively. Resistant genotypes *viz*., Brinjal-85 and Local Long were found to suffer the infestation of 3.30 and 5.51 per cent; registered the lowest total sugar content of 5.45, 5.80 and 3.03, 3.36 mg/g dry weight at initial and final stages of shoot growth, respectively.Tripathi *et al* [58] found the maximum of the total phenol content in the fruits of Pusa Purple Round and Pusa Purple Long. Whileas, in fruits total sugar content was comparatively higher both at initial and final stages of fruit growth. The results are in conformity with Jat and Pareek (2003) who found that varieties *Arka Kusumakar* and SM-10 suffer less infestation by borers and contained less total sugars of 3.56 and 3.66 per cent, respectively. Direct and indirect path coefficients and ANOVA were determined for the L. infestation to brinjal genotypes and are given in **Tables 4, 5** and **6**, respectively.

Table 4 Direct (Diagonal) and indirect effect path coefficients for sugars

Infestations (%)	15 DAT	45 DAT	45 DAT	70 DAT
X2	**-0.008134**	-0.008091	0.964153	0.982508
X3	-0.008502	**-0.008126**	0.964148	0.981917
X4	-0.007225	-0.007942	**0.983812**	0.972005
X5	-0.008701	-0.008331	0.964377	**0.990908**

Residual Effect, 2 = 0.05838057

Table 5 Direct (Diagonal) and indirect effect path coefficients for phenols

Infestations (%)	15 DAT	45 DAT	45 DAT	70 DAT
X2	**-0.3479789**	0.1877329	-0.3138840	-0.4958699
X3	-0.3410193	**0.1915641**	-0.3237961	-0.5167487
X4	-0.3305800	0.1877329	**-0.3304042**	-0.5167487
X5	-0.3305800	0.1896485	-0.3271002	**-0.5219684**
Residual Effect, 2 = 0.008260105				

Table 6 Two way ANOVA of the biochemical composition (Phenols & Sugars) in various genotypes of brinjal, *S. melongena.*

Source of Variation	*SS*	*d.f*	*MS*	*F*	*P-value*	*F crit.*
Rows	333.5536	37	9.014963	36.86284	0.006	1.457048
Columns	166.5953	7	23.79933	97.31717	0.007	2.045035
Error	63.33955	259	0.244554	-		
Total	563.4885	303				

Conclusion and recommendations

The study revealed that the brinjal genotypes commonly grown in Kashmir division (J&K, India) varied significantly in total phenol and total sugar content. However, it was noted that percentage of borer infestation was more in shoots of locally developed hydrids (Shalimar Brinjal Hybrid-1 and Shalimar Brinjal Hybrid-2) as compared to the rest of the commercially cultivated brinjal varieties (Brinjal-85 and Local Long). High heritability coupled with low genetic gain can be improved by development of hybrid varieties.

Gaps in research and recommendations

More work is needed by breeder to opt for selection, screening following hybridization and isolation of desirable transgressive segregants. Without affecting the quality of commercial varieties, the resistance genes identified thus will be transferred to recurrent parents by backcross breeding. Identification of suitable molecular markers which are linked with resistant traits will ease the breeding programme involving insect infestation. The resistant materials will be highly useful to link the resistant traits with molecular markers to map the genes in chromosomes.

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References

[1] Linnaeus, C. (1753). Species plantarum. 1:184–188, Stockholm
[2] Bothara, P.A. 2003. Bioefficacy of different endosulphan formulations against brinjal shoot and fruit borer, Leucinodes orbonalis Guenee. Insect Science.4 (1):103-104.
[3] Mathur, A., Singh, N.P. and Singh, S.2012.Management of Brinjal Shoot and Fruit Borer: Dilemma of Adopting Bt. Brinjal over Integrated Pest Management Technology. International Conference on Clean and Green Energy IPCBEE vol.27 IACSIT Press, Singapore.
[4] Anonymous, 2010. National Horticultural Board (NHB).2010. Area and Production for Horticulture Crops. National Horticulture Board Report, India.pp.1-12.
[5] Daniel, M. 2007. Genetically Engineered Eggplant. Span.pp.41
[6] Anonymous, 2011. Department of Agriculture, Government of Jammu and Kashmir. Annual Report of Estimated Area and Production of Vegetable Crops in Kashmir Division.pp.1-2
[7] Dar, S.A..Wani, A.R., Raja,T.A and Mir, S.H. 2015a. Insect Biodiversity of the Brinjal crop in Kashmir. Indian Journal of Ecology. 42(2):295-299.
[8] Dar, S.A.,Wani, A.R., Sofi, M.A and Pathiania, S.S. 2017a. Integrated pest management for brinjal fruit and shoot borer (Leucinodes orbonalis)- A revive. Indian Journal of Entomology (In press)

[9] Abdullah, M., Al, M., Khandakar, S.I., Mahbuba, J. and Gopal, D. 2014. Effect of spinosad and sex pheromone alone and in combination against the infestation of brinjal shoot and fruit borer, Leucinodes orbonalis Guen.International Journal of Research in Biological Sciences.4(1): 20-24

[10] Mainali, R.P. 2014. Biology and management of eggplant fruit and shoot borer, Leucinodes orbonalis Guenee (Lepidoptera: Pyralidae): Nepal Agricultural Research Council (NARC), Khumaltar, Lalitpur, Nepal. A review.Int J Appl Sci Biotechnol, Vol 2(1): 18-28. DOI.10.3126/ijasbt.v2i1.10001.

[11] Dar, S.A. 2012. Screening of brinjal genotypes/varieties against brinjal shoot and fruit borer in Kashmir. Master's thesis submitted to Department of Entomology, SKUAST-K, and Kashmir.

[12] Krishnaiah, K. 1980. Assessment of crop losses due to pests and diseases. In: Govindu HC (ed), University of Agricultural Sciences Technology Series 33, Bangalore, 259-267.

[13] Saha, T., Nithya, C., Randhir, K. and Ray,S.N.2014. Field Efficacy of Newer Insecticides against Brinjal Shootand Fruit Borer, Leucinodes orbonalis Guenee (Lepidoptera: Pyralidae) in Bihar. Bihar Agricultural University, Sabour 813210, Bhagalpur, Bihar, India. Pesticide Research Journal Vol. 26(1): 63-67.

[14] Purushothaman, G; Sudhkar, D. and Jothieswari. M.2014. Engineering Insect Resistance in Brinjal against Fruit and Shoot Borer Leucinodes orbonalis.International Journal of Advancements in Research & Technology. Volume 2, Issue 6, 206 ISSN 2278-7763.

[15] Koushik, N.R; Manjunatha, M; Naik, M. I; Shivanna, B. K; Narayanaswamy, H; Kalleswara, S. M; Gayathridevi, S. and Pradeep, S. 2013. Evaluation of eco-friendly approaches against brinjal shoot and fruit borer Leucinodes orbonalis (Guenee) (Lepidoptera: Pyralidae).Karnataka J. Agric. Sci., 26 (2): (209-213).

[16] Mishra, K; Keshav, S. and. Tripathi, C. P. M. 2014.Management of infestation of pod borer (Lucinodes orbonalis Guenee) and productivity enhancement of brinjal (Solanum melogena) through vermiwash with biopesticide.International Journal of Advanced Research. Volume 2, Issue 1, 780-789.

[17] Dar, S.A., Padder, S.A., Wani, A.R., Mir, S.H and Sofi, M.A. 2015b. Evaluation of combined options for the management of the brinjal shoot and fruit borer, L.orbonalis Guenee in Kashmir.Journal of Experimental Zoology, India. 18 (1):359-365.

[18] Onekutu, A., Omoloye, A. A. and Odebiyi, J. A. 2014. Integrated pest control of the egg fruit and shoot borer L.orbonalis Guenee on the garden egg Solanum aethiopicum L in Southwest Nigeria.International Journal of Scientific and Research Publications, Volume 4, Issue 7.ISSN 2250-3153.

[19] Dar, S.A., Wani, A.R., Mir, S.H., Nehru, R.K and Jeelani, M.I. 2014a. Relationship between morphological characters of different brinjal genotypes and extent of the infestation by L. orbonalis, Guenee. Green farming. 5(6): 1096-1100.

[20] Dar, S.A., Wani, A.R., Nehru, R.K., Mir, S.H and Jeelani, M.I. 2014b. Physio-chemical characteristics of the brinjal genotypes imparting the tolerance to the brinjal shoot and fruit borer (L. orbonalis) under field conditions of the Kashmir, India. Ecology, Environment and Conservation. 20(4):1605-1611.

[21] Dar, S.A and Wani, A.B. 2017c. Plant secondary metabolites. In Book INSECT. International Research Publication House; B-2/84, Ground Floor, Rohini Sector-16, Delhi-110089,Chapter: 20, pp: 236-264

[22] Dadmal, S.M.,Nemade, S.B. and Akhare, M.D.2004. Field screening of brinjal cultivarsfor resistance to Leucinodesorbonalis Guen. Pest Management in Horticultural Ecosystem. 10 (2):145-150

[23] Hanur, V. S., Reddy, P. V., Bhalewar, S. and Saraswathi, M. S.2010.Solanum macrocarpon, a wild brinjal, is not a source of resistance against brinjal shoot and fruit borer, Leucinodes orbonalis Guenee. Scientific Correspondence.pp. 1-3

[24] Ranjithkumar, L; Patil, B. V; Ghante, V. N; Bheemanna, M. and Hosamani, A. 2014.Baseline sensitivity of brinjal shoot and fruit borer, Leucinodes orbonalis (Guenée) in South India to Cry1Ac insecticidal protein of Bacillus thuringiensis.Current science, 105,No. 3: 366

[25] Preneetha. S, 2002. Breeding for shoot and fruit borer (Leucinodes orbonalis Guen.) resistance in brinjal (Solanum melongena L.). PhD Thesis, Tamil Nadu Agricultural University, Coimbatore.

[26] Doshi, K.M., Bhalala, M.K., Kathiria, K.B.1998. Correlation and path analysis for yield, fruit borer infestation, little leaf incidence and quality traits in brinjal (Solanum melongena. L).Capsicum and Eggplant Newsletter,17: 84-87

[27] Khorsheduzzaman, A. K. M., Alam, M. Z. and Mian, I. H.2010. Biochemical basis of resistance in eggplant (Solanum melongena. L) toLeucinodesorbonalis Guen. and their correlation with shoot and fruit infestation. Bangladesh Journal of Agricultural Research. 35 (1): 149-155

[28] Dar, S.A.,Wani, A.R and Mir, S.H. 2015c. Screening and relative resistance of Brinjal genotypes against L.orbonalis Guenee in Kashmir. Journal of Experimental Zoology, India.

[29] USDA Nutrient Database. 2011. Eggplant. pp. 1-11

[30] Sabolu, S., Keshubhai, B. K., Chintan, R. and Sushil, K. 2014. Generation mean analysis of fruit quality traits in eggplant (Solanum melongena L.). Australian journal of crop science. 8(2):243-250
[31] Mishra, P. N., Singh, Y. V. and Nautiyal, M. C. 1998.Screening of brinjal varieties for resistance to shoot and fruit borer (L. orbonalis) (Pyralidae: Lepidoptera). South Indian Hortriculture. 36 (4): 188- 192.
[32] Ali, M., Muhammad,A., Naureen, R., Muhammad, S. H., Muhammad, A. and Muhammad, A.2014.The susceptibility study of some aubergine (S. melongena L.) cultivars against jassid (Amrasca biguttula biguttula (Ishida). Pak.J. Agri. Sci., Vol. 51(3), 679-683.
[33] Gomez, K. A. and Gomez, A. A. 1984. Statistical procedures for Agricultural Research. John Wiley and Sons, New York. pp.680
[34] Hedge, J.E and Hofreiter, B.T.1962. In: Methods in Carbohydrate Chemistry. Vol.17, (Eds.,) Whistler, R.L. and BeMiller, J.N.,Academic Press, New York, pp. 420
[35] Singh, B.D. 1983. Breeding for resistance to biotic stresses II. Insect resistance In: Plant breeding principles and methods. Kalyani Publishers, Ludhiana, India. pp. 494.
[36] Panda, N. and Khush, G.S.1995. Host Plant Resistance to Insects.IRRI-CABI.p.431
[37] Dhaliwal, G.S and Dilawari, V. K.1993. Advances in Host Resistance to insects. Kalyani Publishers, India. pp. 443
[38] Mohan, S., Jayaraj, S., Purusothaman, D. and Rangarajan, A.V.1987. Use of Azospirillum biofertilizer for the control sorghum shootfly.Current Science.pp.725-734.
[39] Dar, S.A. 2017b. Biochemicals mode of defense against insect pests. In Book INSECT. International Research Publication House; B-2/84, Ground Floor, Rohini Sector-16, Delhi-110089,India.Chapter: 28, pp: 397-409
[40] Kumari1, A., Neena, C. and Ajmer, S. D. 2014. Comparsion of eggplant genotypes for phenolic compounds and other biochemical parameters. International Journal of Advanced Research, Volume 2, Issue 9, 615-622.
[41] Prasad, T.V., Rakesh, B. K.K., Gangopadhyay, M., Arivalagan, M.K., Bag, B.L., Meena, L. and Dutta, M. 2014. Biophysical and biochemical basis of resistance to fruit and shoot borer (Leucinodes orbonalis Guenee) in eggplant. Indian J. Hort. 71(1): 67-71.
[42] Docimo, T., Francese, G., Ruggiero, A., Batelli, G., Palma, M.D., Bassolino, L., Toppino, L.,Rotino, G.L., Mennella, G and Tucci, M. 2016. Phenylpropanoids Accumulation in Eggplant Fruit: Characterization of Biosynthetic Genes and Regulation by a MYB Transcription Factor. Front Plant Sci.6:1233. doi: 10.3389/fpls.2015.01233.
[43] Prabhu, M., Natarajan, S. and Pugalendhi, L. 2007. Biochemical basis of shoot and fruit borer (Leucinodes orbonalis Guen.) resistance in brinjal (Solanum melongena L). In: Keshavachandran R, Nazeem PA,Girija D, John PS, Peter KV (eds). Recent trends in Horticultural Biotechnology, New India Publishing Agency, New Delhi. pp.829-837.
[44] Reddy, E. E. P. and Patel, A. I.2014.Heterosis Studies for Yield and Yield Attributing Characters in Brinjal (Solanum Melongena L.).Journal of Recent Advances In Agriculture.2(2): 175-180
[45] Kaur, G., Bajaj, K.L. and Chadha, M.L.1985.Quality characters in fruits of eggplant (Solanum melongena L.) as affected by maturity. Vegetable Sciences.12 (2): 68-72.
[46] Kalloo, N. 1988. Solanaceous crops. In: Vegetable Breeding.Vol.2.CRC press.INC BOCA Raton, Florida. pp. 520-570.
[47] Amin, S.M.R., Alam, M. Z., Rahman, M. M., Hossain, M. M and Mian, I.H. 2014. Study on Morphological Characteristics of Leaves, Shoots and Fruits of Selected Brinjal Varieties/Lines Influencing Brinjal Shoot and Fruit Borer Infestation. International Journal of Economic Plants, 2014, 1(1):001-008.
[48] Soundarajan, R.P. and Baskaran, P. 2001. Effect of antibiosis components of eggplant on the development biology of whitefly parastoids. Encarsia transvena and Eretmocerus mundus M (Aphelinidae: Hymenoptera).In National Seminar on Sustainable Insect Pest Management,Loyala College, Chennai.pp. 298
[49] Shinde, K.G. 2007. Correlation of physical and chemical characters in brinjal in relation to shoot and fruit borer infestation. Advances in Plant Sciences.20 (2): 613-615
[50] Kalyanaraman, B., Prevovic, P.I., Sealy, R.C. 1987. Semiquinone anion radicals from the addition of amino acids, peptides and proteins to quinines derived from the oxidation of catechols and catechol amines. Journal of Biological Chemistry. 262: 11080-11087.
[51] Pecci, C. D. 2000. Oxidation of ingested phenolic compounds creates oxidative stress in the midgut tissues of Lymantria dispar caterpillars. Department of Molecular, Cellular, and Developmental Biology, Raymond V. Barbehenn, Faculty Sponsor.pp: 8-10.

[52] Summers, C.B., Felton, G.W.1994. Prooxidant effects of phenolic acids on the generalist herbivore Helicoverpa zea (Lepidoptera: Noctuidae): Potential mode of action for phenolic compounds in plant anti herbivore chemistry. Insect Biochemistry and Molecular Biotechnology.24: 943-953.

[53] Isahaqua, N.M.M. and Chaudhuri, R.P.1984. Comparative susceptibility of some varieties of eggplant to shoot and fruit borer in Assam. Indian Journal of Agricultural Sciences.54 (9): 751-752

[54] Panda, R.N. and Das, R.C.1975.Ovipositional preference of fruit and shoot borer (Leucinodesorbonalis Guen.) to some varieties of brinjal. South India Horticulture.22: 46-50

[55] Lapidus, J. B., Cleary, R. W. and Augustine, M. G.1963.Chemical factors influencing host selection by the Mexican bean beetle, Epillachna varivestis Muls. Journal of Agriculture and Food Chemistry. 11: 402-463

[56] Knapp, J. L., Hedin, P. A. and Douglas, W. A. 1965. Amino acids and reducing sugars in silks of corn resistant or susceptible to corn earworm. Annals of Entomology Society of America.58 (3): 401-402.

[57] Kalode, M. B. and Pant, N. C. 1967. Studies on the amino acids, nitrogen and moisture content of maize and sorghum varieties and their relation to Chilo zonellus (Swin) resistance. Indian Journal of Entomology. 29 (2):139-144.

[58] Jat, K.L and Pareek, B.L. 2003. Biophysical and biochemical characters in brinjal against Leucinodesorbonalis Guen. Indian Journal of Entomology.65 (2): 252-258

[59] Tripathi, M., Pratibha, S., Praveen, P., Vankat, R. P. and Harendra, S. 2014.Antioxidant Activities and Biochemical Changes in Different Cultivars of Brinjal (Solanum melongena L.).American Journal of Plant Physiology, 9: 24-31.

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