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SCREENING OF DIFFERENT EGGPLANT (*SOLANUM MELONGENA* L.) VARIETIES FOR RESISTANCE AGAINST EGGPLANT SHOOT AND FRUIT BORER (*LEUCINODES ORBONALIS* G. (LEPIDOPTERA: PYRALIDAE) UNDER SEMI-ARID CONDITIONS

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ABSTRACT

Current experiment was conducted to screen out seven different cultivars of eggplant against eggplant fruit and shoot borer (*Leucinodes orbonalis* G.). The experiment was carried out at Entomological research area, The Islamia University of Bahawalpur, Pakistan during March 2018 to July 2018 as spring sown crop. The trial was carried out according to RCB design having seven treatments (varieties) and four replications. Data was recorded on three different dates (*i.e.* 10-06-2018, 25-06-2018 and 10-07-2018). Results showed that maximum mean percent shoot infestation was recorded on Eggplant F1 Chaya 704 (52.46 ± 2.92%) while minimum mean shoot infestation was observed in Eggplant Long Purple Sky 384 (10.59 ± .95%). Maximum mean fruit infestation was also recorded in Eggplant F1 Chaya 704 (55.99 ± 4.83%) while the lowest mean value was observed in Eggplant Black Boy 706 (13.13 ± 4.36%). Correlation studies showed that there was significant positive correlation between shoot infestation and plant height (r= .260*) and significant positive correlation among fruit infestation and length of fruit (r= .205). After grading of varieties, it was concluded that there was only Eggplant Black Boy 706 placed at resistant grade due to least fruit as well as shoot infestation. Eggplant Black Long US 3715 and Eggplant Rosa Bianca Organic was observed as tolerant varieties against the pest. It was concluded that afore-mentioned varieties contained genetical resistance against eggplant shoot and fruit borer. These varieties should be disseminated in agriculture sector as environmentally safe plant protection measure. Furthermore, superior traits of resistant plants should be genetically evaluated to improve other varieties.

Keywords: Eggplant, Different Varieties, *Leucinodes orbonalis*, Host Plant Resistance, Integrated Pest Management.

INTRODUCTION

Eggplant *Solanum melongena* Linn. (recognized as eggplant in the United States and aubergine in France and England) is one of the few cultivated solanaceous species cultivated from ancient times. It is known as brinjal in its home-grown country, India, where it was domesticated long ago and where the highest diversity is found (Daunay, 2008). It is a well-known vegetable cultivated in warm-humid agro-climatic zones in the world (Hanson *et al.*, 2006) likewise that prevailing in South-East Asian region (Thapa, 2010). Here, eggplant is considered as the most important vegetable of solanaceous family (Kantharajha and Golegaonkar, 2004). Statistical data indicates that eggplant is cultivated on 664000 ha and its total production is 12552000 tonnes in India in 2016 while in Pakistan, it is cultivated on 8483 ha and its total production is 84290 tonnes in 2016 (FAO, 2016).

Several insect pests attack eggplant immediately after transplanting and remain damaging to crop till harvesting. Some of the important insect pests of eggplant in Pakistan are eggplant fruit and shoot borer, *Leucinodes orbonalis* G. (Lepidoptera; Pyralidae), eggplant stem borer, *Euzopheraperticella* R. (Lepidoptera; Pyralidae), leaf roller, *Eublemmaolivacea* W. (Lepidoptera; Noctuidae),Hadda beetle, *Epilachnavigintioctopunctata* Fab. (Coleoptera; Coccinellidae), Cotton aphid, *Aphis gossypii* (Homoptera; Aphididae),Whitefly, *Bemisia tabici* (Gen.) (Homoptera; Alerodydidae), thrips, *thrips palmi* K. (Thysanoptera; Thripidae) (Srinivasan, 2009).

Production loses due to this pest range from 85 to 90 percent (Mishra, 2008). Such extensive use of pesticides limits the eggplant production, makes eggplant expensive to users,

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possesses health hazards, causes environmental pollution and resource deprivation (Alam *et al*., 2003). Management practices of this intolerable pest are inadequate and limited to frequent sprays of chemical insecticides (Latif *et al.*, 2010).

Shaukat *et al.* (2018) revealed that the adult of ESFB is a whitish moth which hide during daytime and activates from dusk to perform various activities like mating oviposition. Damage of the pest belongs to all parts of the plants like inflorescence, fruits and shoots. Larvae bore into fruits and shoots and in younger plants, caterpillars drill into midrib of large leaves. At the time of maturity, damage of the insect on fruits causes a serious loss in yield.

Kaur *et al*. (2004) observed six cultivars of eggplant which were transplanted under net house and field situations. Fruit damage in net house was nearly 50% lower than the fruit injury noted under field conditions. Moreover, cultivars BH-1, BH-2 and Punjab Barsati resulted in significantly higher merchantable fruit yield (554.66-579.66 g/plant) and total fruit yield (729.00-779.33 g/plant) in net house in contrast to 82.00-194.66 g/plant merchantable and 179.00-362.00 g/plant total fruit yields in field conditions.

The implementation of resistant assortments is one of the safest methods to keep away the pests from crops (Hossain *et al*., 2002). The scrutinizing program of various eggplant varieties to investigate natural plant immunity has been undertaken by numerous researchers. Pusa Purple Cluster was very resistant variety in a field evaluation experiments run in India (Lal, 1991). The variety, Nayankajal had been found promising against ESFB infestation in Bangladesh (Hossain *et al*., 2002). A hybrid variety, Sweta, was graded as highly resistant to several species of insect pests of eggplant, including *L. orbonalis*, mealy bug, spotted leaf beetle, leafhopper, aphids and whitefly (Elanchezhyan *et al*., 2008). The implication of resistant cultivars is the environment friendly control measure and can be applied blended with other management practices. Experimentally verified resistant eggplant assortments can be employed in association with other pest control practices to cope this insect pest which is cost-effective and environmentally riskless (Lit, 2009). Varieties to be highly resistant is not complementary however, even a minimum magnitude of resistance is pivotal in managing insect pests when it is collaborated with other control systems which result in plunged use of insecticides (Srivastava, 1993). Different brinjal fruit colours possesses the attraction and repulsion characteristics for ESFB. An experiment conducted by Devi *et al*., (2015) on 18 different brinjal cultivars with seven different types of fruit colours. Out of which greenish purple colours variety was the least preferred by fruit borers with an overall mean fruit damage of 5.21 per cent. Overall highest fruit damage (26.02%) was noticed on infested fruits in the variety of purple colour.

Studies were conducted to examine the result of biophysical characters of plants on the infestation of shoot and fruit borer on various eggplant varieties (Naqvi *et al*., 2009). He concluded that some of the anatomical traits such as diameter of shoots and fruit diameter have significant correlation with borer infestation while length of fruit has significant negative correlation. He also observed that fruit shape and colour have no clear-cut impact on shoot and fruit borer activities.

The present study is conducted to evaluate and screen out the resistant cultivars/varieties under local conditions to limit the extensive and discriminating use of pesticides with following objectives; Field screening of selected brinjal varieties to study their resistance or susceptibility to eggplant shoot and fruit borer and to study the biophysical characters of brinjal genotypes to examine their relation with infestation of shoot and fruit borer.

MATERIALS AND METHODS

Current experiment was conducted to screen out seven different cultivars of eggplant i.e., Black Boy 706, Eggplant F1 Chhaya 704, Eggplant Black Long US3715, Eggplant F1 BSS 914, Eggplant Rosa Bianca Organic, Eggplant F1 Chutu 705, Eggplant Long Purple Sky 384 against eggplant shoot and fruit borer (*Lucinodes orbonalis* Guenee). Eggplant seeds of these varieties were purchased from Sky Seed Store, Lahore, Pakistan. The experiment was carried out at Entomological research experimental area, The Islamia University of Bahawalpur, Pakistan during March 2018 to July 2018 as spring sown crop.

The seeds of eggplant were sown in seven earthen pots with 20 cm diameter in the wire house of The Department of Entomology. The experimental procedure was carried out according to Randomized Complete Block Design with seven treatments (varieties) and four replications. Seeds of selected varieties were sown on 20th March 2018 in fine silty loam soil. Young seedlings emerged after approximately a week later from the time of sowing when temperature and relative humidity were 24^{o}C and 47% respectively. No fertilizers, pesticides and plant growth regulators etc. were used at nursery stage.

Field preparation

After 35 days (25th April 2018), seedlings were transplanted to field, which was irrigated, and transplanting was done in standing water. Seedlings were transplanted from pots to field with naked roots.

Layout of field preparation

At the time of transplanting, prevailing temperature was 39^{o} C and relative humidity was 55 % in the atmosphere. Land was prepared with the help of bed planter. The unit plot size was 1 x 2 m^2 with row to row spacing 80 cm and plant to plant distance was 45 cm. A complete dose of essential nutrients was provided to the crop. Nitrogen (N_2) was provided in the form of synthetic urea, phosphorus (P_2 O_5) in the form of Diammonium phosphate and potassium (K_2O) in the form of Murat of potash commercial fertilizers to all the treatments with fertigation method @ 115, 72 and 75 kg/ha. respectively, Rashid (1999).

Data Recording for Shoot and Fruit Borer Infestation

For shoot and fruit borer infestation, data was recorded by selecting five random plants from a plot. Percentage shoot infestation was recorded as per formula:

$$\% \text{ Infestation} = \frac{\text{Number of shoots infested}}{\text{Total no.of shoots}} \times 100$$

$$\% \text{ Infestation} = \frac{\text{Number of fruit infested}}{\text{Total no.of fruits}} \times 100\%$$

Data was recorded on three different dates with the interval of 15 days (i.e. 10-06-2018, 25-06-2018 and 10-07-2018).

Data recording for bio-physical traits of plants
Bio-physical characteristics were recorded after selecting five randomly plants from each plot. Data from these five plants was taken by three different dates as mentioned previously.

Shoot thickness
The diameter of stems of five randomly selected plants were measured. A measuring tape was used for this purpose. This work was carried out at the time when the plants were attracted by female moths for oviposition.

Length of pedicel
Pedicel lengths of fruits from five randomly selected plants per plot was measured with the help measuring tape from point of attachment to the base of calyx. Data was collected on fruit maturity.

Length of calyx
The same fruit taken for measuring the length of pedicel was used to measure length of calyx. The length of calyx was measured in centimetres with the help of scale from the base of calyx up to the tip and the average per replication was worked out. Data was collected on fruit maturity.

Length of fruits
At the time of harvesting, five mature fruits of average size from five selected plants was selected in four replications and lengths of fruits was measured in cm with the help of vernier calliper and average per replication was worked out.

Diameter of fruits
Diameter of selected fruit was measured in centimetres cross-sectionally with the help of measuring tape and average was worked out for each genotype.

Plant Spread The spread of plants was measured in centimetres with the help of scale at peak growth stage of plants and average was worked out.

RESULTS
Overall, seven different varieties were screened out for resistance or susceptibility against brinjal shoot and fruit borer along with the following results.

Effect of different varieties on means comparison for infestation by *L. orbonalis* and biophysical characters
Shoot infestation
Maximum shoot infestation was found in variety Eggplant F1 Chaya 704 with mean percent infestation **(**52.46 ± 2.92) and minimum infestation was recorded on Eggplant Long Purple Sky 384 (10.59 ± .95) (Table 1; Fig. 1). Analysis of variance shows significant difference among different varieties on the incidence of *L. orbonalis* G. to shoot infestation (F=18.27, df=6, P=.000)

Fruit infestation
Maximum fruit infestation was found in variety Eggplant F1 Chaya 704 with mean percent infestation **(**55.99 ± 4.83) and minimum fruit infestation was recorded on Eggplant Black Boy 706 (13.13 ± 4.36) (Table 1; Fig 2). Analysis of variance shows significant difference among different varieties on the incidence of *L. orbonalis* G. to fruit infestation (F=11.33, df=6, P=.000).

Fig. 1
Infested Shoot from *L. orbonalis*

Fig. 2
Infested Fruit from *L. orbonalis*

Correlation Analysis
Correlation of fruit and shoot infestation was done with different biophysical characters. Results regarding correlation are shown below.
Correlation of shoot infestation with bio-physical characteristics
Correlation studies showed that there was positive but weak correlation between shoot infestation and shoot thickness ®= .079). Correlation studies showed that there was positive correlation between shoot infestation and plant height (r= .260*). There was positive but weak correlation between shoot infestation and plant spread (r= .139) (Table 2).

Correlation of fruit infestation with bio-physical characteristics

There was positive but weak correlation between fruit infestation and length of pedicel ®= .147). Correlation studies showed that there was positive correlation between fruit infestation and length of fruit (r= .205). There was positive but weak correlation between fruit infestation and diameter of fruit (r= .159). (Table 2).

Effect of fruit shape and colour on fruit infestation by *L. orbonalis*

Minimum fruit infestation was observed in Eggplant F1 black boy 706 variety (13.13 ± 4.36%) with fruit shape round and purple colour and maximum infestation was recorded from Eggplant F1 Chaya 704 (55.99 ± 4.83%) with fruit shape round and dark purple colour (Table 3).

Categorization of brinjal genotypes based on the mean percent fruit infestation by *L. orbonalis*

Categorization of brinjal varieties was done for infestation by *L. orbonalis* according to the grading of varieties done by Rashid and Singh (2014) and Devi *et al.* (2015). Table 4 describes the different levels of immunity, tolerance and susceptibility to fruit infestation is as follows

Table 1
Effect of different varieties on means comparison for infestation by *L. orbonalis* and biophysical characters

Varieties	N	Shoot infestation Mean ± SE	Fruit infestation Mean ± SE	Shoot Thickness Mean ± SE	Length of pedicel Mean ± SE	Length of Calyx Mean ± SE	Length of Fruit Mean ± SE	Diameter of Fruit Mean ± SE	Plant Height Mean ± SE	Plant Spread Mean ± SE
1	12	15.18 ± 2.02c	13.13 ± 4.36c	7.67 ± .33a	2.85 ± .29bc	2.76 ± .28bc	5.61 ± .59b	4.07 ± .56c	65.06 ± 1.89bc	79.20 ± 3.33bc
2	12	52.46 ± 2.92a	55.99 ± 4.83b	7.48 ± .31ab	3.21 ± .12ab	3.66 ± .32a	8.82 ± .29a	3.72 ± .13cd	71.37 ± 1.55a	89.54 ± 1.39a
3	12	20.61 ± 2.23c	27.67 ± 4.19b	6.64 ± .25b	3.01 ± .30bc	2.25 ± .24c	8.96 ± .89a	2.91 ± .30d	60.87 ± 1.70c	76.29 ± 2.70c
4	12	37.25 ± 6.46b	47.01 ± 4.56b	7.00 ± .28ab	3.20 ± .13ab	3.27 ± .14ab	6.91 ± .23b	5.23 ± .22b	63.70 ± 1.57bc	79.37 ± 2.89bc
5	12	25.50 ± 3.87c	33.06 ± 4.96a	6.92 ± .26ab	3.34 ± .11ab	3.41 ± .14ab	6.73 ± .25b	6.62 ± .20a	67.39 ± 2.74ab	81.75 ± 2.23bc
6	12	15.99 ± .82cd	49.10 ± 6.52b	7.30 ± .21ab	2.49 ± .25c	2.42 ± .27c	5.28 ± .59b	4.00 ± .40c	64.05 ± 1.93bc	86.27 ± 1.29ab
7	12	10.59 ± .95d	53.83 ± 6.54b	6.86 ± .29ab	3.70 ± .16a	2.47 ± .11c	10.13 ± .76a	3.25 ± .09cd	66.52 ± 1.90abc	79.79 ± 1.87bc
	df	6	6	6	6	6	6	6	6	6
	F	18.27	11.33	1.74	3.33	5.69	10.22	16.23	2.92	3.80
	P	.000	.000	.123	.006	.000	.000	.000	.013	.002
Total	84	26.80 ± 1.87	48.68 ± 2.61	7.12 ± .11	3.11 ± .08	2.89 ± .10	7.49 ± .28	4.26 ± .17	65.57 ± .78	81.74 ± .97

Varieties: 1: Eggs plant black boy 706; 2: Eggplant F1 Chaya 704; 3: Eggplant Black Long US 3715; 4: Eggplant F1 BSS 914; 5: Eggplant Rosa Bianca Organic; 6: Eggplant F1 Chutu 705; 7: Eggplant Long Purple Sky 384

Table 2
Correlation between infestation by *L. orbonalis* and biophysical characteristics

Parameters		Shoot thickness	Plant Height	Plant Spread
Shoot infestation	Pearson Correlation	.079	.260*	.139
	Sig. (2-tailed)	.476	.017	.209
Parameters		**Length of Pedicel**	**Length of Fruit**	**Diameter of Fruit**
Fruit infestation	Pearson Correlation	.031	.051	.160
	Sig. (2-tailed)	.781	.643	.145

Table 3
Colour and fruit shape effect on percent infestation of fruit by *L. orbonalis*

Sr. no	Varieties	Fruit Colour	Fruit Shape	Mean % Fruit Infestation
1.	Eggplant F1 Black Boy 706	Purple	Round	13.13
2.	Eggplant F1 Chaya 704	Purple	Oblong	55.99
3.	Eggplant Black Long US 3715	Dark Purple	Long	50.67
4.	Eggplant F1 BSS 914	Dark Purple	Round	47.01
5.	Eggplant Rosa Bianca Organic	Dark Purple	Round	33.06
6.	Eggplant F1 Chutu 705	Dark Purple	Oval	49.10
7.	Eggplant Long Purple Sky 384	Purple	Long	53.83

Table 4
Categorization of brinjal genotypes based on the mean percent fruit infestation by *L. orbonalis*

Sr. no.	Mean Percentage of fruit infestation	Grade	Varieties
1	0	Immune	None
2	1-20	Resistant	Eggplant F1 Black Boy 706
3	21-40	Tolerant	Eggplant Black Long US 3715 Eggplant Rosa Bianca Organic
4	Above 40	Highly Susceptible	Eggplant F1 BSS 914 Eggplant F1 Chutu 705 Eggplant Long Purple Sky 384 Eggplant F1 Chaya 704

DISCUSSION

In the present experiment, seven eggplant varieties were arranged from local market (Sky Seed Store, Lahore). Different eggplant varieties were evaluated for their resistance to brinjal shoot and fruit borer based on percent infested shoots and fruits.

Data of mean percent infestation indicated that the shoot infestation ranged from (10.59 ± .95) on Eggplant Long Purple Sky 384 to (52.46 ± 2.92) on Eggplant F1 Chaya 704. The level of resistance in Long Purple Sky 384 placed it to resistant grade. Shoots of all eggplant varieties screened were likely to the incidence of *L. orbonalis*. Among seven verities, no one, was found totally resistant to shoot and fruit borer.

Previous literature showed that immune accessions to *L. orbonalis* was stated only either in wild types of eggplant like *S. anomalum* and *S. incanum* (Behera *et al*., 1999) or in the descendants of wild types like Arka Mahima and ArkaSanjivans (Kale *et al*., 1986). But in our investigation, none was invulnerable to *L. orbonalis*.

Correlation between shoot infestation and shoot thickness (r= .079) was positive but weak. On the other hand, investigation of Wagh, (2012) reported that the percent shoot infestation presented positive and highly significant correlation with shoot thickness ®= 0.632**).

Mean fruit infestation indicated the fruit infestation ranged from (13.13 ± 4.36) to (55.99 ± 4.83) of Eggplant Black Boy 706 and Eggplant F1 Chaya 704 varieties respectively. According to the grading of varieties by Rashid and Singh (2014) and Devi *et al.,* (2015) a table describing the different levels of immunity, tolerance and susceptibility to fruit infestation describes that out of seven, four brinjal varieties was fallen in highly susceptible genotypes category. The variety Eggplant Black Boy 706 had fulfilled the criteria of

resistant grade. Eggplant Black Long US 371 and Eggplant Rosa Bianca Organic were evaluated as tolerant varieties of eggplant.

(Krishna *et al.,* 2001) found 43% fruit infestation in Ramy round purple which was relatively the highest susceptible while lowest shoot infestation was described in SM-02. There was negative but weak correlation between fruit infestation and shoot thickness (r= -.123).

Mean shoot thickness from selected varieties ranged from Eggplant Black Long US 3715 (6.64 ± .25 cm) to Eggplant Black Boy 706 (7.67 ± .33 cm). Wagh *et al.,* (2012) discovered highest mean value of shoot thickness which was 0.62 cm not supported by present studies however they measured the thickness from top 2.5 cm below the tip. In this study shoot thickness was measured from the point of borer infestation mostly where off shoots were emerging from plants.

Maximum mean pedicel length was recorded from Eggplant Long Purple Sky 384 (3.70 ± .16 cm) and the minimum one was obtained from Eggplant F1 Chutu 705 (2.49 ± .25 cm). In a wild accession *S. incanum* x Phule Harit, the maximum pedicel length was from the parent P2 (Phule Flarit) recorded maximum (7.79 cm) pedicel length (Shinde, 2004).

Maximum mean value of calyx length was obtained from Eggplant F1 Chaya 704 (3.66 ± .32 cm) and the lowest mean calyx length was recorded from (2.25 ± .24 cm). Maximum mean value of fruit length was recorded from Eggplant Long Purple Sky 384 (10.13 ± .76 cm) and the minimum mean value of fruit length was obtained from Eggplant F1 Chutu 705 (5.28 ± .59 cm).Wagh *et al*., (2012) investigated the highest mean fruit length (13.21 cm) in RHRB-60 accession.

Correlation in present studies described that there was positive but weak correlation between diameter of fruit (r= .159) and fruit infestation. These findings agree with that of Naqvi *et al*., (2009) who found fruit diameter (r= .686**) had strong positive correlation with fruit borer infestation. Subbaratnam (1982) calculated positive strong correlation between diameter of fruit (r= .755**)and fruit infestation.

Maximum mean value of plant height was recorded from Eggplant F1 Chaya 704 (71.37 ± 1.55 cm) and the minimum mean value of plant height was obtained from Eggplant Black Long US 3715 (60.87 ± 1.70 cm). Present study results of plant height were closer to that of Patel *et al.,* (2015) who investigated plant height of the twenty-nine screened varieties was ranged from 74.27 to 115.10 cm.

Maximum mean value of plant spread was calculated from Eggplant F1 Chaya 704 (89.54 ± 1.39 cm) and minimum value was computed from Eggplant Black boy 706 (79.20 ± 3.33 cm).

CONCLUSIONS

Host plant resistance is the key tactic to limit the infestation of pests. Bt cotton and other genetically modified organisms is the best example of resistant plants. On the other hand, management of pests using pesticides is not a feasible option under ongoing crises of environmental pollution. Therefore, there is much need to sort out some environment friendly alternatives to control pests. In this study, an approach is initiated to investigate some local genotypes of eggplant which could be resistant against ESFB. Among all seven varieties tested, no variety was seen to be immune against the pest. However, Eggplant F1 Black 706 was appeared as resistant variety having least pest infestation. Moreover, Eggplant Black Long US 3715 and Eggplant Rosa Bianca Organic was come out as tolerant varieties. It was concluded that afore-mentioned varieties containing powerful genotypes would be an essential asset of agriculture sector in Pakistan. This will help farmers to decrease their expenditure on pesticides and will cause fruitful addition to vegetable yield.

DECLARATIONS

There is no conflict of interest among authors at disclosure. All the data presented in this article is the sole property of the authors and it is going to be published with their consent. There are no financial and non-financial competing interests among authors. There is no source of funding for this study and the whole study was conducted upon the expenses of authors. Muhammad Waqar Hassan was the principal investigator and experiment designer. Muhammad Abdullah Shaukat was the experiment conductor, data collector and writer of the manuscript. Umer Hayat and Gulraiz Malik were crop producer and assistant in data collection. In addition, I would like to acknowledge the administration of The Islamia University of Bahawalpur to grant us access to internet and digital libraries. I also thanks to the farm manager and his team to cooperate us in the crop production practices.

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