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# SCREENING BRINJAL GENOTYPES FOR RESISTANCE TO SHOOT AND FRUIT BORER, *LEUCINODES ORBONALIS* AND ANALYSING THE GEOGRAPHIC DIVERGENCE OF RESISTANCE THROUGH DIVA-GIS

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**ABSTRACT**

Field screening of 52 brinjal (*Solanum melongena*L.) genotypes, sourced from different regions of India covering 14 states, was carried out to evaluate their reaction to the shoot and fruit borer, *Leucinodes orbonalis* Guenee. Among the genotypes screened, four accessions *viz*., IC136347, IC127021, IC111077 and IC013332 were identified as resistant by recording a lower (<10 %) fruit damage, while seven genotypes as fairly resistant; 11 as tolerant; 20 as susceptible and 13 as highly susceptible to *L. orbonalis*. The correlation between morphological attributes and the shoot infestation showed that, the plant spread ($r$ = 0.592 at P < 0.01)and number of primary branches ($r$ = 0.404 at P < 0.01) had a significant positive correlation with the infestation of shoot and fruit borer. The DIVA-GIS analysis revealed that the germplasm collected from the states of Andhra Pradesh, Haryana, Jharkhand and Tripura were found to be having a higher Shannon diversity index (1.109 - 0.832) and coefficient of variation (35% - 60%) indicating a presence of wider range in sources of resistance for *L. orbonalis* in those regions. Targeted germplasm exploration in the identified areas would provide good sources of resistance in brinjal for *L. orbonalis*.

## INTRODUCTION

The shoot and fruit borer, *Leucinodes orbonalis* Guenee is a key pest of brinjal (*Solanum melongena* L.) and it inflicts substantial damage to the crop at all growth stages. The intensity of infestation was found to be over 90% (Mainali, 2014) and the resulting yield loss has been estimated up to 95% (Naresh *et al*., 1986) in brinjal. The pest infestation also reduces the content of vitamin C in fruit up to 80% (Sharma, 2002). *L. orbonalis*is distributed all through the vegetable growing regions of India and fruit damage due to the pest was reported to be up to 72% in Delhi (Prasad *et al*., 2014); 61% in Punjab (Kaur *et al*., 2014); 100% in Uttarakhand (Khan and Singh, (2014); 30 % in Himachal Pradesh (Bhatia *et al*., 1995); 36% in Chhattisgarh (Devi *et al*., 2015); 31% in Jharkhand (Bhushan *et al*., 2011); 16% in Rajasthan (Naqui *et al*., 2009); 80% in Gujarat (Jhala *et al*., 2003); 47% in Maharashtra (Wagh *et al*., 2012); 70% in Andhra Pradesh (Sasikala *et al*., 1999); 52% in Odisha (Tripathy *et al*., 1997); 38% in Tamil Nadu (Elanchezhyan *et al*., 2008); 78% in Karnataka (Jagginavar *et al*., 2010); 79% in Meghalaya (Rai *et al*., 2005) and 64% in Andaman Nicobar Islans (Prasad *et al*., 2007).

The cryptic habitat of the *L. orbonalis* and their ability to infest the crop from seedling stage to maturity make the pest management very difficult, resulting in preventive or excessive use of pesticides which in turn increases the cost of cultivation tremendously. Never the less, pesticides are still widely used to control the pest, though the indiscriminate application has posed problems of high residues in fruits; destruction of natural enemies and development of resistance to multiple classes of insecticide (Raju *et al*., 2007). Cultivars having inherent resistance to *L. orbonalis* has the potential to improve the marketable yield and enhance economic returns of the farmers. Several screening trials have been attempted for identifying resistance sources to *L. orbonalis* (Prasad *et al*., 2014; Khan *et al*., 2014; Javed *et al*. 2011, Elanchezhyan *et al*., 2008). However, an enormous scope exists in finding resistant sources to *L. orbonalis* asa sizable portion of the 4,343brinjal accessions (NBPGR, 2015) conserved at the National gene bank of NBPGR still remains untapped. In this context, the present investigation was carried out to screen 52 brinjal genotypes for their reaction to *L. orbonalis* and to expedite their morphological attributes of resistance to the pest. An attempt was also made to map the diversity of resistance in the screened brinjal genotypes using geographical information system to elucidate genetic and geographic patterns in distribution of resistance to the brinjal shoot and fruit borer.

## MATERIALS AND METHODS

Two supervised field experiments were conducted to screen 52 brinjal genotypes for their reaction to brinjal shoot and fruit borer (*L. orbonalis*) at the research farm of NBPGR Regional station, Rajendranagar, Hyderabadduring the summer seasons of 2012-13 and 2013-14. The brinjal (*S. melongena*) genotypes were sourced from different regions of the country covering Andaman and Nicobar Islands, Andhra Pradesh, Bihar, Haryana, Himachal Pradesh, Jharkhand, Karnataka, Kerala, Karnataka, Meghalaya, Odisha, Telangana, Tripura and West Bengal.The experiments were laid out an augmented block design with four check verities in four blocks (*Bhagyamathi* resistant; *Pusa Purple Long* and *Pusa Shyamala* moderately resistant and IC136564 - susceptible) and the checks were repeated after every 13 test genotypes. The seedlings were raised in pots under green house conditions and transplanted after 40 days of sowing into three rows of 5m length for every accession witha spacing of 90 cm between rows and 50 cm between plants. Recommended agronomic package of practices were adopted for raising the crop excluding the plant protection measures.

Data on the healthy and damaged shoots by *L. orbonalis* were recorded on individual plant basis for all treatmentsat fortnightly intervals from 45 to 120 days after treatment (DAT) and per cent shoot infestation was worked out. The damaged shoots were removed after each observation as described by Mishra *et al.* (1988). Morphological traits on plant height, plant spread and number of primary branches were recorded at peak flowering stage. The fruit infestation by *L. orbonalis* was recorded at every harvest on both number and weight basis from all the plants in each accession. Data on pedicel length, fruit length and fruit breadth were recorded at the time of harvesting on randomly selected five fruits of marketable maturity and the shape and colour of fruit was recorded visually as per the minimum descriptors for brinjal (Srivastava *et al.*, 2001).The genotypes were categorized on the basis of mean per cent fruit damage into, immune (0% fruit infestation); highly resistant (1-10%); moderately resistant (11-20%), tolerant (21-30%), susceptible (31-40%) and highly susceptible (above 40%) based on the rating by Mishra *et al.* (1988).

The data obtained from field experiments were analysed at the Indian NARS Statistical Computing Portal (IASRI, 2015) using the analysis of variance for augmented block design (Gomez and Gomez, 1984). The per cent infestation values were subjected to arcsine transformations and the treatment means were compared using Fisher's Least Significant Difference (LSD) test at P=0.05. Correlations were calculated between per cent fruit infestation and morphological traits of the plant and fruit. The data was subjected to GIS analysis (DIVA-GIS version 7.5) by plotting the data on fruit infestation of individual accessions corresponding to their georeferenced points. Grid maps on brinjal diversity were generated on the basis of Shannon diversity index and coefficient of variation (Hijmans *et al.*, 2012) for the genotypes based on fruit infestation.

## RESULTS AND DISCUSSION

The brinjal genotypes recorded a wider gamut of reaction to *L. orbonalis* in terms of shoot and fruit infestations (Table 1). The pooled mean data of the both seasons (summer 2012-13 and 2013-14) showed that the per cent shoot infestation ranged from 1.92 per cent (IC136347) to 39.51 per cent (IC136364). The local checks recorded an infestation of 14.70, 15.48, 13.11 and 34.79 per cent for *Bhagyamathi*, *Pusa Purple Long*, *Pusa Shyamala* and IC136564, respectively. Seventeen accessions (IC136347, IC013332, IC111077, IC127021, IC089510, IC304974, IC138024, IC089867, IC090788, IC136343, IC144013, IC136617, IC096932, IC136359, IC126721, IC136311 and IC136380) recorded a shoot infestation level of less than 10 per cent. The screening trials by earlier workers also confirmed a wider range of shoot infestation by *L. orbonalis* in different years *i.e,* 10.20 to 14.07% (Panda *et al.*, 1971); 5.01 to 20.40% (Dhankar *et al.*, 1977); 4.79 to 42.04% (Dhooria and Chadha, 1981); 0.95 to 7.05% (Subbratnam, 1987); 8.00 to 28.60%(Elanchezhyan *et al.*, 2008) and 7.18 to 35.58% (Devi *et al.*, 2015).These reports on infestation levels clearly indicate that, *L. orbonalis* retained its position of key pest status in brinjal over the last five decades despite the changing scenario of pest in several other crops.

The data on per cent fruit infestation (Table 1) showed a significant variation among the genotypes on both number and weight basis. The accessions were classified into different categories of resistance (Table 2) based on the pooled mean value of fruit infestation recorded on both number and weight basis. The results showed, IC136347 was found to be recording the lowest fruit infestation (5.62%) while the susceptible local check IC136564 (74.33%) recorded the highest. No genotype was found to be immune to *L. orbonalis,*while four accessions *viz.*, IC136347, IC127021, IC111077 and IC013332 were categorised as resistant. Among the 52 genotypes screened, 7 were rated as fairly resistant; 11 were found to be tolerant; 20 as susceptible and 13 as highly susceptible to *L. orbonalis*. The check, Pusa Shyamala also graded as resistant, while the Bhagyamathi and Pusa Purple Long were found to be fairly resistant in the present study. In a similar screening trial involving 23 brinjal genotypes Prasad *et al.* (2014) identified five resistant accessions (IC280954, IC099723, IC111013, IC111033 and EC038474) against the pest. Khan *et al.*, (2014) screened 192 genotypes of brinjal tested and identified two immune (EC305163 and IC090132), three resistant and 21 fairly resistant genotypes to *L. orbonalis*.

In the present screening trials, morphological characters *viz.*, plant height (from 41.70 cm in IC090972 to 87.55 cm in IC096932); plant spread (from 34.10 cm in IC136347 to 131.70 cm in IC136364) and the number of primary branches (from 1.95 cm in IC304974 to 6.90 in IC137751) varied significantly among the genotypes(Table 1). The fruit shape and colour did not very much, as most of the fruits were oblong in shape and green or purple in colour with irregular stripped colour distribution, while the fruit pedicel length varied from 2.70 cm (IC089867) to 5.95 cm (IC099696). The results on the correlation between the morphological attributes and pest infestation (Table 3) revealed that, theplant spread ($r$ = 0.592 at $p<0.01$) and number of primary branches ($r$ = 0.404 at $p<0.01$) had a significant positive correlation with the shoot infestation, while the plant height and have no influence on the shoot damage.The fruit infestation also had a similar positive correlation with the plant spread ($r$ = 0.530 at $P<0.01$) and number of primary branches ($r$ = 0.359 at $P<0.01$). The morphological parameters recorded on fruit *viz.,* pedicel length, fruit length, breadth, shape, colour and colour

**Table1: Morphological characters of brinjal fruit in relation to *L. orbonalis* infestation during summers 2011-12 and 2012-13 (Pooled mean for two seasons)**

| Accession | Plant height (cm) | Plant spread (cm) | No of primary branches | % Shoot infestation$ | Fruit pedicel length (cm) | Fruit length (cm) | Fruit breadth (cm) | Fruit shape[1] | Fruit colour[2] | Fruit colour distribution[3] | % Fruit infestation (no. basis)* | % Fruit infestation (wt. basis)* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IC013332 | 43.60 | 39.30 | 4.10 | 3.44(10.69) | 3.95 | 5.45 | 4.45 | 7 | 7 | 5 | 8.33(16.77) | 8.83(17.27) |
| IC082880 | 65.75 | 96.65 | 4.25 | 20.80(27.12) | 3.30 | 5.55 | 4.85 | 5 | 2 | 5 | 33.28(35.21) | 42.59(40.72) |
| IC089510 | 62.00 | 81.10 | 6.15 | 4.44(12.16) | 5.40 | 8.40 | 6.80 | 7 | 2 | 5 | 14.23(22.15) | 13.81(21.80) |
| IC089867 | 83.35 | 73.00 | 4.05 | 4.78(12.62) | 2.70 | 5.35 | 3.25 | 7 | 2 | 5 | 12.99(21.11) | 13.38(21.44) |
| IC090063 | 55.70 | 92.30 | 5.60 | 26.23(30.8) | 2.90 | 5.45 | 4.45 | 5 | 2 | 5 | 60.44(51.01) | 65.28(53.87) |
| IC090070 | 51.45 | 41.25 | 5.65 | 11.50(19.82) | 3.05 | 7.35 | 3.90 | 7 | 7 | 5 | 35.07(36.3) | 34.37(35.88) |
| IC090731 | 73.70 | 79.50 | 4.85 | 19.64(26.3) | 4.05 | 8.10 | 4.05 | 7 | 2 | 5 | 49.48(44.68) | 46.01(42.7) |
| IC090788 | 51.00 | 90.80 | 5.15 | 5.19(13.17) | 3.65 | 8.05 | 4.35 | 7 | 2 | 5 | 20.29(26.76) | 24.35(29.56) |
| IC090949 | 52.05 | 74.20 | 4.05 | 16.52(23.97) | 3.90 | 6.60 | 5.95 | 5 | 2 | 1 | 35.29(36.43) | 33.88(35.58) |
| IC090972 | 41.70 | 97.95 | 4.05 | 11.19(19.54) | 4.55 | 3.55 | 3.90 | 5 | 7 | 5 | 33.21(35.17) | 35.86(36.77) |
| IC096932 | 87.55 | 47.20 | 5.05 | 8.55(16.99) | 3.55 | 7.90 | 3.55 | 7 | 2 | 5 | 31.90(34.37) | 38.28(38.2) |
| IC099696 | 55.55 | 62.80 | 3.60 | 15.55(23.22) | 5.95 | 13.60 | 7.10 | 7 | 2 | 5 | 27.38(31.54) | 29.00(32.57) |
| IC111077 | 43.80 | 102.85 | 3.90 | 3.51(10.8) | 2.95 | 6.10 | 4.45 | 7 | 7 | 5 | 7.51(15.9) | 9.61(18.05) |
| IC126636 | 53.70 | 83.95 | 3.41 | 10.02(18.45) | 4.45 | 7.60 | 4.05 | 7 | 7 | 5 | 21.41(27.55) | 20.77(27.1) |
| IC126640 | 71.60 | 97.25 | 6.80 | 15.25(22.98) | 2.90 | 4.95 | 4.75 | 5 | 2 | 5 | 32.59(34.8) | 33.57(35.39) |
| IC126721 | 73.20 | 66.15 | 5.60 | 8.82(17.26) | 4.05 | 6.80 | 5.35 | 7 | 2 | 5 | 21.34(27.51) | 23.05(28.68) |
| IC127021 | 66.80 | 45.60 | 4.85 | 3.98(11.51) | 5.05 | 10.65 | 7.10 | 7 | 7 | 5 | 6.37(14.61) | 6.24(14.46) |
| IC136281 | 54.50 | 80.75 | 5.35 | 10.44(18.84) | 5.05 | 5.85 | 4.35 | 7 | 8 | 1 | 33.46(35.33) | 31.12(33.9) |
| IC136287 | 64.15 | 84.80 | 4.75 | 11.55(19.86) | 4.55 | 6.90 | 5.75 | 5 | 2 | 5 | 31.39(34.06) | 37.66(37.84) |
| IC136311 | 51.90 | 74.95 | 5.85 | 9.72(18.16) | 5.35 | 8.25 | 5.20 | 7 | 2 | 5 | 22.40(28.24) | 21.51(27.62) |
| IC136321 | 73.75 | 79.90 | 5.05 | 10.15(18.57) | 3.85 | 6.60 | 5.60 | 5 | 2 | 5 | 30.94(33.78) | 33.41(35.3) |
| IC136326 | 66.85 | 88.40 | 4.55 | 14.07(22.02) | 5.15 | 8.40 | 5.90 | 7 | 8 | 1 | 35.44(36.52) | 42.52(40.68) |
| IC136343 | 59.75 | 68.55 | 3.95 | 5.82(13.96) | 4.20 | 6.65 | 4.75 | 7 | 7 | 3 | 22.75(28.47) | 24.09(29.38) |
| IC136345 | 71.20 | 97.25 | 5.55 | 16.94(24.29) | 5.40 | 13.05 | 5.40 | 3 | 7 | 5 | 36.20(36.97) | 46.33(42.88) |
| IC136347 | 58.35 | 34.10 | 4.05 | 1.92(7.97) | 4.20 | 7.60 | 4.85 | 7 | 8 | 1 | 5.71(13.82) | 5.54(13.61) |
| IC136359 | 57.40 | 73.15 | 4.90 | 8.66(17.11) | 4.85 | 7.55 | 4.85 | 7 | 2 | 5 | 32.32(34.63) | 33.29(35.22) |
| IC136364 | 72.25 | 131.70 | 6.25 | 39.51(38.93) | 4.85 | 8.40 | 5.70 | 7 | 7 | 5 | 69.57(56.5) | 75.13(60.06) |
| IC136367 | 70.75 | 89.40 | 5.95 | 15.12(22.88) | 4.15 | 9.30 | 5.75 | 7 | 7 | 5 | 32.31(34.63) | 31.67(34.23) |
| IC136380 | 62.80 | 76.75 | 5.05 | 9.80(18.24) | 4.60 | 9.90 | 6.30 | 7 | 7 | 5 | 20.95(27.23) | 19.48(26.18) |
| IC136383 | 68.85 | 98.90 | 6.10 | 21.52(27.63) | 3.85 | 9.35 | 7.10 | 7 | 8 | 5 | 45.99(42.68) | 55.18(47.96) |
| IC136440 | 66.95 | 89.45 | 5.95 | 15.14(22.89) | 4.60 | 9.85 | 5.15 | 7 | 2 | 5 | 36.67(37.25) | 35.20(36.38) |
| IC136445 | 51.30 | 97.20 | 5.35 | 16.53(23.98) | 5.25 | 8.25 | 5.85 | 7 | 7 | 5 | 26.45(30.94) | 28.56(32.29) |
| IC136552 | 63.50 | 94.10 | 5.25 | 15.89(23.48) | 5.90 | 7.95 | 5.75 | 7 | 2 | 5 | 50.94(45.52) | 61.13(51.41) |
| IC136617 | 56.00 | 72.50 | 4.35 | 7.77(16.18) | 4.55 | 9.15 | 6.20 | 7 | 7 | 5 | 21.13(27.35) | 22.37(28.22) |
| IC136775 | 56.10 | 83.95 | 5.83 | 11.33(19.66) | 4.85 | 9.25 | 5.55 | 7 | 7 | 5 | 26.11(30.72) | 33.42(35.3) |
| IC137681 | 66.10 | 83.10 | 5.75 | 11.25(19.59) | 5.15 | 8.60 | 5.10 | 7 | 8 | 5 | 34.29(35.83) | 33.26(35.2) |
| IC137689 | 53.15 | 90.25 | 6.05 | 15.21(22.94) | 3.75 | 7.80 | 5.15 | 7 | 7 | 5 | 38.31(38.22) | 39.46(38.9) |
| IC137702 | 77.55 | 80.05 | 4.65 | 10.15(18.57) | 5.05 | 11.00 | 6.25 | 7 | 2 | 5 | 39.64(39.01) | 42.81(40.85) |
| IC137751 | 63.50 | 105.65 | 6.90 | 29.42(32.83) | 4.05 | 7.50 | 5.90 | 7 | 7 | 5 | 62.87(52.43) | 61.61(51.69) |
| IC137766 | 73.20 | 87.10 | 4.85 | 11.90(20.17) | 4.40 | 7.00 | 6.10 | 7 | 7 | 5 | 35.30(36.44) | 32.83(34.94) |
| IC138024 | 73.20 | 62.20 | 2.90 | 4.71(12.53) | 5.35 | 9.45 | 6.25 | 7 | 7 | 5 | 17.57(24.77) | 21.08(27.32) |
| IC144013 | 57.95 | 71.20 | 4.05 | 6.28(14.5) | 5.05 | 8.40 | 6.40 | 7 | 8 | 5 | 11.05(19.41) | 10.61(19.00) |
| IC144075 | 77.40 | 107.55 | 6.15 | 30.66(33.61) | 4.15 | 8.40 | 6.50 | 7 | 2 | 5 | 65.52(54.02) | 70.76(57.25) |
| IC144080 | 67.15 | 101.45 | 6.50 | 23.79(29.18) | 4.65 | 11.15 | 5.45 | 7 | 7 | 5 | 50.84(45.46) | 61.01(51.34) |
| IC146655 | 75.65 | 111.40 | 6.15 | 31.26(33.98) | 5.05 | 9.90 | 6.30 | 5 | 8 | 1 | 66.79(54.79) | 70.74(57.23) |
| IC146667 | 81.70 | 87.45 | 5.90 | 13.47(21.52) | 4.35 | 10.30 | 7.30 | 7 | 2 | 5 | 32.62(34.82) | 41.75(40.24) |
| IC169087 | 71.50 | 100.75 | 6.90 | 23.15(28.75) | 4.65 | 9.45 | 6.30 | 7 | 2 | 5 | 37.05(37.48) | 35.94(36.82) |
| IC174227 | 72.70 | 87.10 | 5.05 | 12.71(20.88) | 3.45 | 8.10 | 5.65 | 7 | 2 | 5 | 40.74(39.65) | 41.96(40.36) |
| IC201231 | 56.00 | 87.35 | 5.05 | 13.31(21.39) | 5.85 | 9.85 | 7.20 | 7 | 7 | 5 | 36.17(36.96) | 39.07(38.67) |
| IC284828 | 59.75 | 88.85 | 5.90 | 15.08(22.85) | 5.75 | 10.45 | 6.80 | 7 | 8 | 1 | 34.76(36.11) | 34.06(35.69) |
| IC304974 | 62.00 | 61.30 | 1.95 | 4.50(12.24) | 5.55 | 11.20 | 6.45 | 7 | 7 | 5 | 13.72(21.73) | 12.76(20.92) |
| IC546259 | 71.05 | 86.65 | 5.85 | 11.89(20.16) | 2.75 | 4.65 | 2.80 | 7 | 2 | 5 | 29.95(33.16) | 27.85(31.84) |
| Bhagyamathi | 71.04 | 88.79 | 6.05 | 6.42(14.7) | 3.24 | 5.74 | 4.41 | 5 | 7 | 5 | 10.62(19.01) | 12.89(21.04) |
| PusaPurple Long | 46.75 | 71.39 | 5.83 | 7.21(15.48) | 4.81 | 16.83 | 3.55 | 3 | 7 | 1 | 15.20(22.79) | 15.97(23.42) |
| PusaShyamala | 75.07 | 87.77 | 5.90 | 5.19(13.11) | 3.44 | 5.48 | 4.14 | 7 | 2 | 5 | 8.26(16.82) | 10.17(18.69) |
| IC136564 | 54.68 | 55.39 | 3.41 | 33.17(34.79) | 3.85 | 8.36 | 4.64 | 7 | 7 | 5 | 68.22(55.43) | 80.45(63.67) |
| CD at 5% | 7.23 | 10.26 | 0.84 | (4.56) | 1.21 | 1.34 | 0.49 | - | - | - | (5.03) | (4.87) |
| CV (%) | 11.30 | 9.48 | 6.73 | 4.82 | 8.82 | 10.01 | 5.91 | - | - | - | 4.81 | 4.76 |

Figures in parentheses are angular transformed values;$ Mean of 12 observations; * mean of 6 harvests; [1]Fruit Shape (3-Long; 5-Round; 7-Oblong; 9-Oval); [2]Fruit colour: (1-Milky white; 2-Green; 7-Purple; 8-Purple black; 9-Black); [3]Fruit colour distribution: (1-Uniform; 3-Mottled; 5-Irregular striped; 7-Regular striped)

**Table 2: Categorisation of brinjal accessions based on the mean per cent fruit damage**

| Fruit infestation | Brinjal accessions (mean % fruit damage) | Total numbers | Grade |
|---|---|---|---|
| 0 | Nil | 0 | Immune |
| 0-10 | IC136347 (5.62), IC127021 (6.31), IC111077 (8.56), IC013332 (8.58), Pusa Shyamala (9.21) | 5 | Resistant |
| 11-20 | IC144013 (10.83), Bhagyamathi (11.76), IC089867 (13.18), IC304974 (13.24), IC089510 (14.02), Pusa Purple Long (15.58), IC138024 (19.32) | 7 | Fairly Resistant |
| 21-30 | IC136380 (20.21), IC126636 (21.09), IC136617 (21.75), IC136311 (21.96), IC126721 (22.2), IC090788 (22.32), IC136343 (23.42), IC136445 (27.51), IC099696 (28.19), IC546259 (28.9), IC136775 (29.77) | 11 | Tolerant |
| 31-40 | IC136367 (31.99), IC136321 (32.18), IC136281 (32.29), IC136359 (32.81), IC126640 (33.08), IC137681 (33.77), IC137766 (34.07), IC284828 (34.41), IC136287 (34.53), IC090972 (34.54), IC090949 (34.58), IC090070 (34.72), IC096932 (35.09), IC136440 (35.93), IC169087 (36.49), IC146667 (37.19), IC201231 (37.62), IC082880 (37.93), IC137689 (38.88), IC136326 (38.98) | 20 | Susceptible |
| >41 | IC137702 (41.23), IC136345 (41.26), IC174227 (41.35), IC090731 (47.75), IC136383 (50.58), IC144080 (55.92), IC136552 (56.03), IC137751 (62.24), IC090063 (62.86), IC144075 (68.14), IC146655 (68.76), IC136364 (72.35), IC136564 (74.33) | 13 | Highly Susceptible |

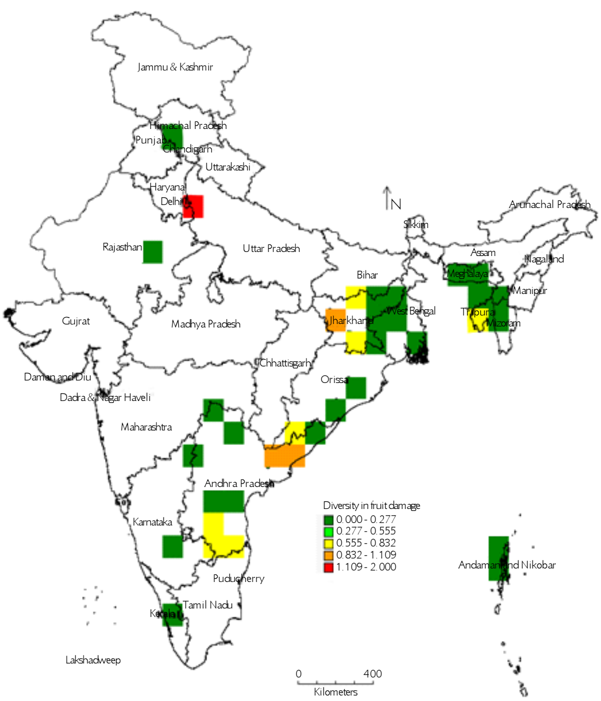


**Figure 1: DIVA-GIS grid map for diversity in brinjal shoot and fruit borer damage**

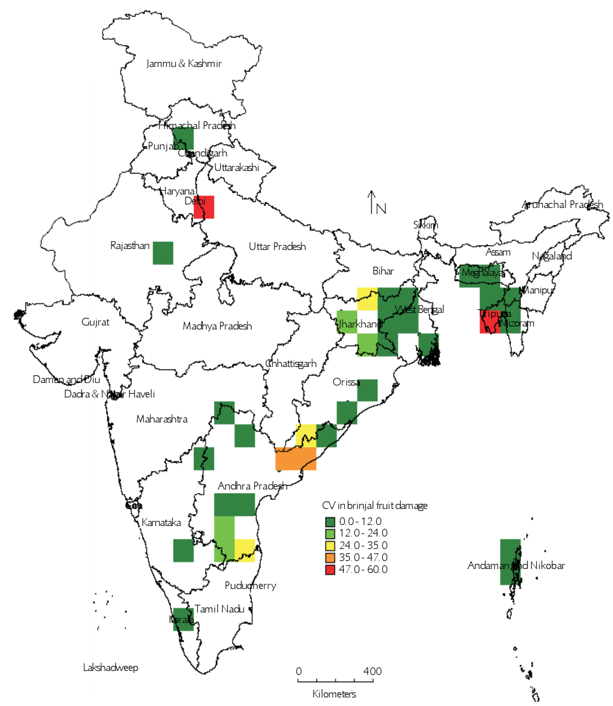


**Figure 2: DIVA-GIS grid map for coefficient of variation in brinjal genotypes with respect to shoot and fruit borer damage**

distribution had no correlation with either shoot or fruit infestation.

Several correlation studies were undertaken in brinjal, associating the agro-morphological traits and damage levels by *L. orbonalis*. Shukla *et al.* (2001) and Naqvi *et al.* (2009) found no correlation between the plant height and shoot infestation by *L. orbonalis*. Javed *et al.* (2011) reported a positive correlation ($r$ = 0.319) between the number of primary branches and fruit infestation; similarly Amin *et al.* (2014) also reported a positive relationship ($R^2$ = 0.69) between number of primary branches and percent shoot infestation. The present findings are in agreement with these reports. The correlation between morphological characters of fruit and infestation by *L. orbonalis* was thoroughly studied by several workers. Shukla *et al.*, (2001); Jat and Pareek (2003); Wagh *et al.* (2013) and Prasad *et al.* (2014) found no significant correlation between fruit length and breadth and *L. orbonalis* infestation and our results are in conformity with the earlier findings. However, Naqvi *et al.* (2009) and Amin *et al.* (2014) found a negative correlation between fruit length and infestation, while Subbaratnam (1982) and Naqvi *et al.* (2009) reported a negative correlation between fruits diameter and infestation. With respect to fruit pedicel length, Wagh *et al.* (2013) and Patil and Ajri (1993) reported a positive significant correlation

**Table 3: Correlation between the morphological traits and infestation of*L. orbonalis*in brinjal**

| | Plant height | Plant spread | No of primary branches | % shoot infestation | Fruit pedicel Length | Fruit length | Fruit breadth | Fruit shape | Fruit colour | Fruit distribution colour | % Fruit infestation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Plant Height | 1 | | | | | | | | | | |
| Plant spread | 0.177 | 1 | | | | | | | | | |
| No of primarybranches | .270* | .520** | 1 | | | | | | | | |
| % Shoot infestation | 0.188 | .592** | .404** | 1 | | | | | | | |
| Fruit pedicel Length | -0.14 | 0.012 | -0.114 | 0.003 | 1 | | | | | | |
| Fruit Length | 0.033 | -0.057 | 0.042 | 0.085 | .610** | 1 | | | | | |
| Fruit Breadth | 0.145 | 0.155 | 0.048 | 0.189 | .612** | .464** | 1 | | | | |
| Fruit Shape | 0.07 | -0.183 | -0.1 | -0.1 | 0.101 | -0.115 | 0.198 | 1 | | | |
| Fruit colour | -.353** | -0.05 | -0.137 | -0.004 | .276* | 0.203 | 0.127 | 0.041 | 1 | | |
| Fruit Colour Distribution | 0.173 | 0.091 | 0.03 | 0.009 | -0.193 | -0.159 | 0.011 | 0.242 | -.306* | 1 | |
| % Fruit infestation | 0.233 | .530** | .359** | .922** | 0.022 | 0.056 | 0.15 | -0.074 | -0.066 | 0.017 | 1 |

** Correlation is significant at the 0.01 level (2-tailed).

with fruit infestation. Though we found a positive correlation between these parameters, it was not significant. Lal *et al.* (1976); Darekar *et al.* (1991) and Naqvi *et al.* (2009) found that the colour of brinjal fruit had no impact on the infestation of borer. However, Grewal and Dilbagh (1995) observed that green coloured fruits were less susceptible to the pest than the dark purple and white coloured fruits. Amin *et al.* (2014) also observed that the green colour fruits in *S. torvum* were significantly less susceptible for the pest infeststion. With respect to fruit shape, Naqvi*et al.* (2009) found that the shape had no clear cut impact on the infestation of fruit borer. The host plant resistance is a complex mechanism, where a comprehensive understanding of morphological and biochemical traits of resistance and their probable interactions have to be deliberated thoroughly for each parameter.

The DIVA-GIS grid map generated by plotting the diversity of brinjal accessions (classified based fruit infestation) is furnished in Fig.1. The accessions sourced from Haryana were found to be having the highest Shannon diversity index range (1.11-2.00)with respect tofruit damage and the accessions sourced from Andhra Pradesh and Jharkhand were also found to be having a significant high range diversity (0.83-1.11). A medium level in diversity index (0.55 - 0.83) was observed for the accessions sourced from Bihar, Jharkhand, Odisha, Tripura and Andhra Pradesh. The DIVA-GIS map plotted on the basis of the coefficient of variations calculated with respect to *L. orbonalis* infestation levels is provided in Fig. 2. Accessions sourced from Haryana and Tripura recorded the highest range of coefficient of variation (47- 60%), while the accessions collected from Andhra Pradesh revealed a significantly higher range of CV (35-47%), indicating the presence of genotypes having diverse range of reaction for the pest. Odisha and Bihar states recorded a moderate range (24-35%) while the other states recorded a low range of CV (< 12%). Based on the GIS analysis, we could conclude that germplasm collected from the states of Haryana, Andhra Pradesh, Jharkhand and Tripura could provide a good sources of resistance in brinjal for *L. orbonalis*. GIS mapping is being effectively used for the diversity analysis, documentation, identifying gaps in the collection and utilisation of plant genetic resources as evidenced by the studies on identifying areas of high diversity in brinjal (Kumar *et al.*, 2013); *Canavalia* accessions possessing a wider range in fatty acids (Sivaraj *et al.*, 2010) and diversity studies on linseed (Sivaraj *et al.*, 2009)and medicinal plants (Varaprasad *et al.*, 2007). Though its potential is not fully comprehended in plant protection arena, few attempts were made to utilise the tool in pest mapping and modelling. Ganeshaiah *et al.*, (2003) successfully used DIVA-GIS in predicting the potential distribution of sugarcane wooly aphid *Ceratovacuna manigera* Zehntner in South India.

The present study had resulted in identification of a fair number of resistant lines amongst a wider collection of indigenous brinjal germplasm. Based on the mean shoot and fruit infestation, the accessions IC136347, IC127021, IC111077 and IC013332 were categorised as resistant sourced to *L. orbonalis*. The identified source of resistance would be of immense use in the breeding programmes for the development resistance verities in brinjal for the shoot and fruit borer. Further exploration could be undertaken in the states of Haryana, Andhra Pradesh, Jharkhand and Tripura for identifying good sources of resistance in brinjal for *L. orbonalis*.

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