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Assessment of biophysical and biochemical bases of resistance in brinjal against major insect pests

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Abstract
Brinjal (*Solanum melongena* L.) is widely grown vegetable of tropical and subtropical parts of the world. Numerous factors are accountable for the short productivity of brinjal, as it is subjected to attack by number of insect pest right from nursery stage till harvesting. In this process the adaption of insect pests to host plants involved behavioral and metabolic changes which enabled insect to cope with the physical and chemical defense systems of plants during evolution. But, Considerable progress has been made in identification and development of crop cultivars with resistance to the major pests in brinjal crop. Host plant resistance (HPR) mechanism is a significant, effective, economical and environmental friendly process in for major insect pest control. There is a need to use breeding approaches to transfer of resistance genes into high-yielding cultivars with adaptation to different agroecosystems. Resistance to insects should form one of the criteria to release varieties and hybrids for cultivation by the farme.

Keywords: Biophysical and biochemical, brinjal, *Solanum melongena* L.

Introduction
Brinjal (*Solanum melongena* L.) is an essential solanaceous vegetable rich in proteins, minerals, vitamins & dietary fiber and polyphenols which acts against obesity, cancer, aging, diabetes, inflammation, neurological diseases and promotes a healthy complexion hair and increased energy. Although, brinjal's poor productivity is due to the occurrence of diverse pests & diseases. Nevertheless, host plant resistance will be suitable either as an entire control measure or as a part of the IPM program with minimal pesticide dependency. Host plant traits including morphological or structural properties interact with the behaviour of insects such as oviposition, feeding, and food ingestion.

Besides, insect pests are affected by biochemical plant compounds. Taking advantage of host plant resistance through breeding strategies would be highly advantageous in developing superior, high-yielding genotypes with resistance to major brinjal pests (Prabhu *et al.* 2009) [36]. Considering these details, the related literature is reviewed and summarized with the subheadings below.

1. Resistant sources against major pests of brinjal.
2. Biophysical basis of resistance to major pests of brinjal.
3. Biochemical basis of resistance to major pests of brinjal.
4. Association of characters, genetic variability, path coefficient analysis & genetic divergence in brinjal genotypes for major pests of brinjal.

Resistant sources against major pests of brinjal
The most important method used for improvement of brinjal in India is selection from indigenous germplasm and evaluation of germplasm gives significant data to classify the material. Germplasm collection, maintenance and its evaluation for economically important traits is a pre-requisite for starting any breeding programme for the genetic improvement of the crop (Shinde *et al.* 2012) [43].

Resistant sources for fruit & shoot borer, Jassid and whitefly
The sources of resistance identified in deferent brinjal genotypes agains brinjal fruit and shoot borer are furnished under here:

Table 1: Resistant sources for brinjal fruit & shoot borer

Sl. No	Resistant brinjal genotypes for *L. orbonalis*	Reference
1	SM-88, *Solanum indicum* and *S. incanum*	Nair (1983) [31]
2	Singnath	Kabir *et al*. (1984) [22]
3	Black Beauty and Florida Market	Duodo (1986)
4	*Solanum gilo*	Tejarathu *et al*. (1991) [51]
5	Arka Kusumakar, Arka Shirish and Neelam.	Srinivas and Peter (1995) [48]
6	Arka Kesav, Arka Neelkanth, Arka Nidhi and SM 6–6	Chaudhary and Sharma (2000) [8]
7	CO-2, Pusa Kranthi, Arka Kusumakar and Manjari Gota.	Daliya (2001) [10]
8	Jumki-1 and Jumki-2	Begum *et al*. (2003) [4]
9	Sweta and Ravaiya	Elanchezyan *et al*. (2008)
10	*Solanum viarum*	Prabhu *et al.* (2011)
11	Brinjal -85	Showket *et al.* (2014) [44]
12	EC 305163 and IC 090132	Rashid and Singh (2014) [39]
13	SM-44	Kranthi Rekha and Celine (2015) [25]
14	AB7–2	Dinesh *et al.* (2015) [13]
15	IC136347, IC127021, IC111077 and IC 013332	Rameash *et al.* (2015) [37]
16	IC 545884 and IC 410129	Suresh *et al*. (2017) [50]

Table 2: Resistant sources for Jassid and whitefly in brinjal genotypes

Sl. No	Resistant sources	Jassid/Whitefly	Reference
1	Manjari Gota and Vaishali	Jassid	Gaikwad (1991) [17]
2	Long Violet and Purple	Jassid	Cassi *et al*. (2000)
3	IBR-174 and IBR-7	Jassid	Sonali Deole (2008) [47]
4	SM 363, SM 364, SM 366, SM 384, SM 385	Jassid	Malini *et al.* (2013) [28]
5	Hybrid 888, Black Pearl, Hybrid 3715 and Nirala	Jassid	Yousafi *et al*. (2013) [53]
6	AB-8/5,	Jassid	Dahatonde *et al.* (2014) [9]
7	Pusa hybrid 6 and IC354694	Jassid	Suresh *et al.* (2017) [50]
8	AB-8/6	Whitefly	Dahatonde *et al*. (2014) [9]

Biophysical basis of resistance to major pests of brinjal

Plant resistance is regulated by several morphological factors such as stem solidity, trichomes, surface waxes, cuticle, cell wall thickness, rapid plant tissue proliferation, anatomical adaptations of organs, etc. The resistance mechanisms associated with morphological (or) structural plant features reduce normal insect feeding (or) oviposition (or) lead to the action of other mortalities factors (Kogan, 1994).

Biophysical basis of resistance against *L. orbonalis*

Oatman (1959) [32] believed that thick pubescence on the leaves of Elokeshi, black beauty, Giant banaors and H-165 make them limited attractive to the grown-up moth (*L. orbonalis*) to deposit their eggs and that the newly hatched larvae cannot bore easily into their fruit. Later, Srinivas and Basheer (1961) observed that the brinjal varieties Coimbatore, H-128 (Cluster White), H-129 (IC-1855), and H-158 (Gudiatham) were tolerant to shoot & fruit borer and the tolerance was due to toughness of skin and pulp of the fruit.

Panda *et al*. (1971) [33] found that larval entry in the resistant varieties is impaired by thick cuticle, thin pithy stem & pointed unicellular trichomes. Webster (1975) found that the mechanical resistance factors like the solidness of stem, tissue's thickness, anatomical adoptions, and structures for the protection of the plants have proven resistance against shoot and fruit.

Krishnaiah and Vijay (1975) [26] noted that the minimum susceptibility to shoot and fruit borer in brinjal varieties Beckwai and Musk Brinjal (IHR 191) is due to the hardiness of fruit skin and flesh. Later, Lal *et al*. (1976) observed that the resistance in brinjal against shoot & fruit borer is due to tight-packed seeds in fruit mesocarp found in *Solanum incanum*, *S. integrifolium*, and *S. khasianum.*

Dhooria and Chadha (1981) [12] reported that the round fruited varieties are more attacked than long fruited varieties by shoot and fruit borer. Similarly, Ahmed *et al*. (1985) observed that the long narrow fruits had less infestation by *L. orbonalis.*

Mishra *et al*. (1988) [30] noted that the shoot & fruit borer resistance in long fruited variety Katrain-4 is due to anatomical characteristics such as tightly arranged mesocarp seeds, thick skin of fruit, and tightly packed pulp vascular bundles.

Dhankar (1988) [11] observed two long fruited type varieties namely S-5 & PPL despite thick fruit skin, hard pulp and tightly arranged seeds showed high susceptibility. Similarly, susceptibility increased as the days to first bloom were more. Likewise, Singh and Chadha (1991) reported that the resistance in SM -17- 4; PBR-129-5 & Punjab Barsati against *L. orbonalis* could be associated with a more number of small-sized fruits/plant along with late and longer fruiting period.

Grewal and Singh (1992) [18] stated that the shoot thickness, leaf area, and pre-flowering period correlate with the shoot infestation. Later, Patil and Ajri (1993) reported a negative correlation of seeds fruit^{-1}, yield plant^{-1} & fruit skin thickness with fruit infestation. Similarly, Pradhan (1994) proved that long fruited varieties were less infested than those with spherical fruits.

Ali *et al.* (1994) [1] reported that the brinjal varieties with hair & prickle characteristics on leaves; stems & fruit stalks resulted in lower percentage infestation of fruit as compared to those without hair & prickles for brinjal shoot & fruit borer.

Hossain *et al*. (2002) [21] observed that the key characteristics of resistant by tolerant varieties were the brinjal genotypes with thick cuticle, large and dense collenchymatous area [hypodermis], compact parenchyma cells in the cortical tissue, a small area in the cortical tissue, more vascular bundles with smaller spaces in the interfascicular region, & compact arrangement of lignified vascular tissue cells & small pith.

Gupta and Kauntey (2008) [19] observed that varieties with dark purple or white coloured fruits were more susceptible (damage 54.65- 64.00 percent) and those with light purple, purple or green colour were less susceptible (24.38-36.05%) and also reported that the varieties with less RLPS (Gulabi Dorla, Punjab Chamkila, Baingan Sada Bahar) suffered more fruit damage (36.05%) and Varieties (SM 17-4, PPC) with less RLSA (0.30) suffered less fruit damage as compared to other varieties(damage > 28.06%).

Chandrashekhar *et al.* (2009) [7] reported that the brinjal resistant genotype, HLB-12 manifested 29% less damage against BR-112 which demonstrated 42-61.5% damage as highly susceptible variety and the resistance was positively attributed to pericarp and mesocarp thickness and compactness of seed ring. Moisture contents, crude protein, and nitrogen showed positive correlation but total sugar; fiber contents, tannin, potassium, and manganese were negatively affected.

Biophysical basis of resistance against *A. devastans, B. tabaci,* and *H. vigintiocto punctata*

Gaikwad (1991) [17] reported that the leaf thickness, midrib thickness, and leaf area were positively associated with the infestation levels of *A. biguttula biguttula*. The length of trichome and density of trichome on leaves were negatively associated with the degree of infestation level.

Rath (2005) described that the resistant varieties such as Bhanjanagar local; Pipili 5 & BB 60 C as having increased egg, grub, pupal & adult duration as compared to moderately resistant varieties such as BB 26, Banki Local & BB 44. Male: Female ratio was found to be higher in both resistant as well as moderately resistant varieties than susceptible check variety (KB White). The check variety didn't favour the development cycles of egg, grub, pupal & adult but caused more female appearance & considered for comparatively better population build-up with greater growth index.

Naqvi *et al.* (2008) revealed that the characters of leaf, *viz.*, area of the leaf, the thickness of leaf & content of chlorophyll, did not affect the population of leafhopper, while the density of trichome had negatively correlation. In different varieties density of trichomes ranged from 550.8 to 1068.5 cm^{-2}. The area of the leaf had a significantly positive effect on the whitefly population, while the thickness of leaf, density of trichomes & chlorophyll content had a non-significant effect on whitefly.

SonaliDeole (2008) [47] stated that the jassid favored cultivars with smooth textured leaves over those with leathery textured leaves or leathery foliage with spines.

Wagh *et al*. (2012) [52] record that amid the biophysical traits trichome density showed negatively strong correlation (r = -0.621) concerning shoot infestation although, positively strong correlation (r = 0.632) was recorded between shoot thickness & percent shoot infestation. The fruit traits *viz.*, fruit length & diameter, the thickness of pericarp & fruit colour of brinjal genotypes screened did not have a clear cut effect on the fruit borer preference, whereas, pedicel length & calyx length showed a highly positive significant correlation.

Malini *et al.* (2013) [28] recorded resistance in brinjal for jassids on the bases of morphological & anatomical and reported that the high midrib hair density and longer midrib hairs in the resistant accessions were showed to impart resistance to jassids.

Biochemical basis of resistance against major pests of brinjal: A large-scale display of chemical elements including inorganic chemicals, primary and intermediary metabolites and secondary elements are known to confer resistance to a spacious kind of insect pests. Broadly, the chemicals granting resistance to insects can be classified into nutrients, allelochemicals and nutrient - allelochemical interactions. The insects feeding on resistant plants exhibit symptoms ranging from acute or lethal to subchronic (Anantha krishnan, 1994) [2].

More amount of silica and crude fibre content in the shoots of resistant cultivars sceptically affected the survival, growth, pupal period, sex ratio and fecundity of brinjal fruit and shoot borer (Panda and Das, 1975) [34]. Later, Bajaj *et al*. (1989) [3] reported that low incidence of fruit borer infestation is associated with higher levels of glycoalkaloids, peroxidase and polyphenol in fruits. Similarly, Gaikwad (1991) [17] reported that the total level of sugars, free amino acids and polyphenols in the leaves of brinjal was negatively associated with the numbers of infesting *A. biguttula. biguttula*.

Hazra *et al*. (2004) [20] observed that thick terminal shoot, long and wide calyx and plumpy fruits of high weight imparts susceptibility while low moisture, sugar and protein content were correlated with tolerance to shoot and fruit borer.

The silica contents, poly phenol oxidase, phenylalanine ammonia lyase, peroxidase, glycoalkaloids and lignin content showed a highly negative and amino acids, crude protein, ash and sugar content (total and reducing sugars) showed a highly positive correlation with shoot and fruit borer infestation (Doshi, 2004) [14]. In the same year, Martin (2004) [29] noticed higher phenyl alanine ammonia lyase (PAL) activity in the wild relatives of brinjal, which dispensed higher resistance against fruit and shoot borer in India and also observed more lignin content linked with the lowest shoot and fruit borer infestation in *S. sisymbrifolium*

Elanchezhyan *et al*. (2009) [16] confirmed that binjal hybrid Swetha shows highly resistant to shoot and fruit borer. Swetha recorded the ash content (12.3%) and total phenols (7.6 mg g^{-1}) while Bejo Sheetal shows highly susceptible to shoot and fruit borer in this low ash content (10.1%) and also total phenols (1.9 mg g^{-1}) was recorded. Absolutely, there was significant negative relationship between total phenols and ash contents with shoot damage.

Prabhu *et al*. (2009) [36] noticed a greater level of polyphenol oxidase movement in interspecific cross F_6 EP65 x *S. viarum.* Consequently, clear correlation exists between the biochemical constituents of superior genotypes and resistance to fruit and shoot borer. Later, Khorsheduzzaman *et al*. (2010) [23] reported that the highest quantities of lignin indicated to minimize shoot and fruit infestation by the borer.

Association of characters, genetic variability, path coefficient analysis, genetic divergence in brinjal genotypes for major pests of brinjal.

Performance of yield and other yield attributing characters as well as resistance to major pests and diseases is highly depends on evaluation of the genotypes. The genotypes performing well in a particular location can be released as a variety or can be used in breeding programmes.

Khurana *et al*. (1988) [24] evaluated and found that the percentage of infestation of fruits with *Leucinodes orbonalis* was negatively correlated with fruits and positively correlated with mean weight, fruit diameter, total leaves, branches per plant and plant height.

Path analysis conducted by Kumar and Ram (1998) [27] revealed that diameter, weight and volume of the fruit could be used as the implied negative selection criteria for devoloping resistance to shoot and fruit borer. Further, Behera *et al.* (1999) [5] made known that high genotypic and phenotypic coefficients of variation of yield and percentage of infested fruits per plant in Eight eggplant genotypes and four related *Solanum* spp, *viz., S. gilo, S. incanum, S. anomalum and S. indicum*.

Heritability is a measure of genetic relationship between the parent and progeny. Possibility of fixing the characters depends on selection methods and also higher the heritable variation. Genetic advance is useful to predict the effect of selection. Heritability along with genetic advance studies plays important role to judge whether the experiential variation for a specific character is due to genotype or environment (Singh and Gopalakrishnan, 1999) [46].

Sheena (2000) [42] noticed that the shoot and fruit borer resistance in land races S_1, S_{13}, S_{28}, S_{35}, S_{36} and S_{37}. In this negative correlation was noticed between fruit borer incidence and fruits per plant. Similarly, Sharma and Swaroop (2000) [8] revealed that the mutual relationship between various characters and determines the component characters on which selection can be based for improvement in yield measured by correlation coefficient analysis. Measuring the direct and indirect effects of all component towards yield through path coefficient analysis would help in recognizing the reliable characters contributing to yield

Genetic architecture and the mode of inheritance of characters are important considerations to determine the breeding procedures. Yield existing a polygenic character, it is largely inclined by the environmental variations. Therefore, direct selection on the basis of phenotypic variability is rarely effective as the response to selection depends upon the magnitude of genetic variability and degree of heritability. Furthermore, partitioning of variability into heritable and non-heritable components will enable to know the effectiveness of selection (Singh and Kumar, 2005). Similarly, Rai *et al*. (2005) observed that expression of fruit and shoot borer resistance prominently affected by non-additive gene.

Senapathi and Senapathi (2006) [40] studied 15 diverse genotypes of brinjal for genotypic correlation coefficients and path coefficients among yield and yield related traits and reported that percentage of infested shoots per plant had negative direct effect on fruit yield.

Prabhu *et al*. (2009) [36] revealed that the genotype coefficient of variation was found to be more for fruit and shoot borer infestation in four interspecific crosses of aubergine *EP 65 Solanum viarum, S. viarum MDU 1, EP 45 solanum, and Co 2 S. viarum*.

Ramesh Kumar *et al*. (2012) [38] identified 33 local types of brinjal to suitable parents of hybridization based on estimated mean performance and genetic variability. High assessment of genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were observed. Correlation and path coefficient analysis with 25 F1 hybrids in brinjal by Thangamani and Jansirani (2012) revealed that fruit borer incidence had negative direct effect on yield.

Panja *et al.* (2013) [35] examined 15 brinjal genotypes through path analysis and reveals direct and indirect effects of different growth and yield characters on yield of healthy and *Leucinodes orbonalis* infested genotypes. Simple correlation studies of these parameters with yield under two conditions recorded that fruit number per plant had the highest significant positive correlation followed by fruit stalk length and fruit length in both the cases. Partitioning of correlation values through path analysis study showed that fruit stalk length and fruit length in both the cases exhibited direct significant positive and negative effect on fruit yield, respectively. Further, he concluded that fruit stalk length and fruit number per plant should be given priority when selection for the varietal improvement would be taken up even from both fields.

Sujin *et al.*, (2017) [49] noticed the High heritability along with high estimates of GCV, genetic advance and genetic gain were observed for fruit yield per plant, fruit weight, number of secondary branches per plant and shoot and fruit borer incidence.

Conclusion

Considerable progress has been made in developing techniques to screen and diverse plant sources tested with resistance to insect pests under natural and artificial infestation. There is a need to establish insect rearing facilities to undertake screening and breeding for resistance to insects in different crops. Resistance to insects should be given as much emphasis as yield to identify new varieties and hybrids for cultivation by the farmers.

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