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Genetic studies in brinjal (*Solanum melongena* L.) for resistance to shoot and fruit borer

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Brinjal or eggplant (*Solanum melongena* L.) is native of India and extensively grown in all South East Asian countries. It is highly productive and usually finds like place as poor man's vegeable. It is popular vegetable crop cultivated throughout the warmer regions of the world. Several biotic and abiotic factors contribute to looses in production of brinjal. Among the biotic stress factors that hamper the production of brinjal, the shoot and fruit borer (*Leucinodes orbonalis* Guen) is the most serious one which occurs throughout the year at all the stages of the crop growth. The loss caused by this deleterious pest was reported to be aound 30-70 per cent by various workers. Management of this pest by use of chemicals may reduce the pest attack to a greater extent, but it causes adverse effects on evnrionment and human health. The productivity of brinjal in India is low 16.9 t/ha as compared to other countries. The main reason for high yield in other countries is utilization of F_1 hybrids. The hybrid vigour will be the highest in F_1 hybrids which serve as a means to increase yield. Combining high yield and resistance/ tolerance to shoot and fruit borer would be a welcome feature. Before initiating any breeding programme, one must have enough information about the ways and means by which the resistance can be exdploited. Although many scientists have reported screening of various germplasm of brinjal for resistance to shoot and fruit borer along with the physical and chemical characters responsible to borer attack; meagre work has been done to understand the inheritance of the same. Review of published research work is confined only to specific aspects and they are discussed under following sub-headings.

- Nature of damage
- Sources of resistance
- Physical and chemical characters for resistance
- Genetics of various characters

Nature of damage :

The damage caused by shoot and fruit borer (*Leucinodes orbonalis* L.) in brinjal starts soon after the transplanting and countries till harvest of the immature but edible fruits. The life cycle of this pest is 19-28 days. The eggs are laid singly on ventral surface of leaves, on flower buds and occasionally on young frits. In young plants, the caterpillars bore into petioles, midrib of leaves, young shoots and feed within, as a result, the affected leaves dry and drop off. The growing point is killed in case of shoot damage. In later stage of crop growth, the caterpillar bores into flower buds and fruits, making them partially unfit for consumption (Lal and Ahmed, 1965). Since the pest acts as shoot borer in early stages and fruit borer in later stages, higher incidence of shoot infestation would normally lead to higher incidence of fruit infestation would normaly lead to higher incidence of fruit infestation. Panda *et al.* (1971) observed similar trend in most 13 entries screened. The infestation of *Leucinodes* was studied on aubergine in Bihar, India, during *Kharif* 1990-91. A larval population peak, on fruits of different cultivars occurred from the 4th week of October to 2nd week of December, however, larval population fruits in most of the cultivars were positively correlated with the maximum and minimum temperature (Shah *et al.,* 1995). Losses due to *Leucinodes orbonalis* varies from year to year and location to location. It is reported to be higher in *Kharif* as compared to summer season (Pawar *et al.*, 1987 and Krishnaiah and Vijay, 1975). The yield loss reported due to this pest are 30 to 70 per cent (La, 1964; Singh and Kalda, 1997; Mishra and Mishra, 1996; Kumar and Shukla, 2002).

Sources of resistance :

The wild species of *Solanum viz.*, *Solanum incanum* and *Solanum integrifolium* which were used as resistant source in the present investivations have been reported to be resistant to shoot and fruit borer by the number of research workers. Lal *et al.* (1976) reported that five wild species of brinjal *viz., S. sisymbrifolium, S. xanthocarpum, S. nigrum, S. khasianum* and *S. integrifolium* were always found free from shoot and fruit borer infestation whilie *Solanum incanum* had 5.3 to 8.6 per cent infestation during different years. The percentage damage on fruit weight basis was generally more than that of fruit number basis. Kale *et al.* (1986) also reported that the wild species of *Solanum* were immune to shoot and fruit borer infestation. Punjab Barsati, an early maturity aubergine variety exhibited 1.4 per cent damage to fruit borer which was 84.8, 47.8 and 32.2 per cent less than in Punjab Chumkila, R 34 and PPL, respectively (Chadha and Sindhu, 1987). Studies on incidence of *L. orbonalis* in aubergine showed that out of 150 tested SM 17-4, PBR 129-5 and Punjab Barasati were the most resistant (Singh *et al.*, 1991). Mote (1979) in a field trial conducted in Maharashtra, reported a minimum fruit infestation of 11.51 per cent in Arka Kusumkar. Resistant cultivars to *L. orbonalis* were reported by many scientists such as Pusa Purple Long (Patel *et al.*, 1995), Pusa Purple Cluster-2 (Dhankar *et al.*, 1977) Anamalai and S-8 (Dhooria and Chadha, 1981), in Assam, Kuchia (Isahque and Chowdhery, 1984) in Bagladesh, Singnath Long (Ahmed *et al.,* 1985) in Haryana, PPC-2 and Aushey (Dhankar *et al.*, 1977) in Andhra Pradesh, SM-204 (Raju *et al.*, 1987) in Orisa, Pusa Purple Cluster (Das and Singh, 1990) in Maharashtra, PBR-120-5 (Darekar *et al.,* 1991) in Bihar, MHR, Kachbachia and Annapurna (Shah *et al.*, 1995) in Bangalore, Arka shirish and Neelam (Shrinivas and Peter, 1995) in Gujarat, PPL, PPC, Pusa Kranti (Patel *et al.*, 1995) in Pantnagar (Singh and Kalda, 1997) in Palampur, Himachal Pradesh, Arka Keshva, Pusa Anupam, Punjab Barasati, SM-6-7, SM 141, CHES-243 and DBL-V-4 were identified as farily resistant (Sharma *et al.*, 2001). Yadav *et al.* (2003) reported that the PPC, Pusa Kranti, PPL, Neelam long, Black Beauty and BR-112 were least susceptible cultivars to this pest. However, thought the number of cultivars tolerant to fruit and shoot borer have seen reported but there was no consistency.

Dhankar *et al.* (1977) classified *S. sisymbrifolium* as tolerant to shoot and fruit borer in normal and ratoon crops. Baksha and Iqbal (1979) reported field resistance in *S. incanum, S. khasianum, S. macranthum* and *S. mammosum*. Kale *et al.* (1986) reported *S. incanum, S. xanthocarpun, S. khasianum* and *S. sisymbrifolium* to be immune to shoot and fruit borer.

Gangopadhyay *et al.* (1996) reported that *S. incanum* was resistant to shoot and fruit borer as compared to other species. Tejavathu *et al.* (1991) reported *S. gilo* and *S. manomalum* as resistant to *L. orbonalis*.

Singh and Kalda (1997) in an experiment conducted at IARI, New Delhi, India, reported *S. gilo* and *S. manomalum* to show high degree of resistance to *L. orbonalis*. Since *S. gilo* is compatible with *S. melongena* it can be used in breeding aubergines resistant to *L. orbonalis*.

Studies in Karnataka, India, confirmed resistance in *S. macrocarpum* with aubergine (Kumar and Sadashive, 1996).

Behara and Singh (2002) reported that interspecific hybrid can be utilized for transfer of shoot and fruit borer resistance genes as well as other agronomically desirable traits from the wild relatives to the cultivars of egg plant. Sharma *et al.* (2001) indentified that the liens with 17F_1 cross fairly resistant to *L. orbonalis*.

Shinde (2004) concluded that the cross *S. incanum* x Ruchira showed promise for field tolerance to shoot and fruit borer. The susceptibility to shoot and fruit borer was dominant character in all F_1's. The resistant genotypes had more number fruits per palnt, thicker fruit skin, small fruit shape, less fruit growth, late fruiting and less shoot thickness as compared to susceptible genotypes in all four crosses as per the mean performance a characters under study. The resistant genotypes had lower total sugars, nitrogen, potassium and zinc while higher total phoenols, iron calcium, crude fibre, ash and silica in their fruit and shoots. These parameters might be responsible for resistant to shoot and fruit borer attach.

Physical and chemical characters responsible for resistance:

Physical and chemical constituents of the plants are known to impart resistance against pests and diseases. Physical and chemical attributes such as plant structure, fruit shape, spiness of leaves, branches, petioles, calyx of fruits, fruit skin thickness and shoot thickness, chemical attributes such as ash, crude fibre, silica, sugars, mineral contents, total phenol contents of fruits and shoots of brinjal are reported to be involved towards the shoot and fruit borer resistance in brinjal.

Krishnaiah and Vijay (1975) reported that the lower susceptibility of varieties to borer incidence was might be due to hardness of the fruits skin.

Lal *et al.* (1976) concluded that the resistant varieties had tightly arranged seeds in the mesocarp of the fruit.

Kale *et al.* (1986) reported that wild types and resistant varieties were of dense pubescent type, having comparatively more number of trichomes. These varieties had more or less tight calyx, though fruit skin, more seediness and highly arranged seeds in mesocarp of the fruits. Similar findings were also reported by Sharma *et al.* (2001).

Bhutani *et al.*(1977), Isahaque and Choudhary (1984) opinioned that the plants with better spread, more height, long and slender fruits were less susceptible to *L. orbonalis* than those with less spread and dwarf structure. The number of shoots per plant played a significance role in reducing per cent shoot damage.

Pradhan (1966) observed that long narrow fruited brinjal varieties were less infested than spherical fruited as the larvae bore more successfully in round fruits than long fruits Grewal *et al.* (1995) attributed resistance of cv. SM-17-4, PPC and brinjal green long to long or extra longer fruits with narrow pericarp.

Mote (1979) recorded fruit skin thickness in some selected varieties along with susceptible check but could not establish any relationship with larval entry, however, Patil and Ajri (1993) observed that thick skinned brinjal were less susceptible to *L. orbonalis*, as it restricted the larval entry.

Singh *et al.* (1991) reported that resistance of SM-17-4, PBR 129-5 and Punjab Barasati was attributed to small sized fruits per plant with shorter inter or intra-cluster distance.

Kumar and Ram (1998) after screening 40 brinjal accessions for resistance to fruit and shoot borer, reported that fruit diameter and fruit volume were effective criteria for selection for resistance/tolerance of aubergines to *L. orbonalis*.

Panda (1999) reported that attack of *L. orbonalis* on brinjal fruits was restricted by tightly packed seeds in the mesocarp. He further found that varieties having fruits with loose calyx were more susceptible to fruit borer than those having fruits with tight calyx.

Dahiya *et al.* (1985) attributed the tolerance of PPC-2 to thorns on plant or small and hard fruits while Annamalai to densely pubescent leaves.

Gangopadhyay *et al.* (1996) screened 27 germplasms and two wild species of brinjal and reported that resistance was not conferred by any single character like spineness, shape and size of fruits or arrangement of seeds.

Panda *et al.*(1971) reported that resistant varieties like H. 408, Black Pendy and Thorn Pendy recorded higher yield than susceptible varieties exhibited higher yield potential than susceptible varieties.

Singh *et al.* (1991) reported that the resistance was attributed to a large number of small sized fruits per plant with shorter intercluster distance, late fruiting and longer fruiting period. The shoot damage was also governed by the number of shoots per plant. If there were large number of shoots then there was less damage.

Sridhar *et al.* (2001) reported that three wild species of brinjal *viz., S. khasianum, S. viarum* and *S. incanum* were found to be resistant to fruit infestation (0.5 to 10.0 %). Further it was observed that in genotypes with relatively long fruits and tightly arranged seeds, the attack of this pest was less. Among the cultivated lines, CHB-103, CHB-187 and 259 were identified as fairly resistant under Bhubaneshwar (Orrisa) conditions.

Ghosh and Senapati (2001) concluded that the PK-123 and Pant cultivars of brinjal were least susceptible to *L. orbonalis* due to their relatively tough skin, hard to semihard pulp and tight to semi-tight arrangement of seeds, whereas Pusa Purple Long and Pundiburi were most susceptible cultivars due to their narrow, long fruits, soft fruit skin and pulp and loosely arranged seeds.

Sharma *et al.* (2001) reported that Arka Keshva was found resistant to this pest. It was observed that attack of *L. orbonalis* was comparatively less in the genotype having less fruits with tightly arranged seeds in the mesocarp.

Shinde *et al.* (2009) reported that the correlation studies with physical character revealed that the per cent infested fruits had significant positive correlation with per cent infested fruit weight, total fruit weight, fruit length, calyx length and fruit growth. The per cent infested shoots had significant positive correlation with shoot thickness.

Biologists have long recognized the specificity of insects for plants, different kinds of insects respond differentially to various secondary chemicals occurring in plants. Of the expressions of plant resistance that are chemical, the so-called secondary plant compounds appear to be dominant. In most cases they modify or control insect growth, development and reproduction, but others such as antifeedents modify behaviour. As genetic studies become more sophisticated the assignments of the role of individual genes in directing biosynthesis of resistance compounds will be expedited (Heden, 1982).

Panda and Das (1975) observed that higher silica and crude fibre in the shoots of resistant varieties. They also observed that higher ash and less sugars in resistant varieties. Resistant varieties had about 20 per cent ash in fruits while susceptible varieties recorded 11.8 per cent.

Darekar *et al.* (1991) and Isahaque and Chodhary (1984) reported lower content of total sugars in resistant brinjal varieties as compared to susceptible varieties.

Raju *et al.* (1987) found less protein content determined in the form of total nitrogen in fruits of moderately resistant variety SM 204 than in the susceptible check SM-82. They further observed that low N, K and Zn and high amounts of P, Ca, Fe, Mn, Cu and phenols were implicated with the moderate resistance of varieties to the shoot and fruit borer. They also observed higher zinc content in susceptible varieties.

Bajaj *et al.* (1989) reported that phenolic compounds may be responsible for resistance to attack by *L. orbonalis* in brinjal cultivar SM-17-4.

Panda and Das (1975) reported that higher silica content conferred resistance in plants against *L. orbonalis*. Panda (1999) reported that low potassium and high phosphorus content contributed towards resistance reaction. He also reported that low percentage of nitrogen restricted the attack of *L. orbonalis*.

Darekar *et al.* (1991) reported lower polyphenol content in susceptible varieties and higher content in resistant varieties.

Jat and Pareek (2003) reported that the biochemical characters such as total sugars, free amino acids and protein were positively corrected with fruit borer infestation while total phenols and negative correlation.

Shinde *et al.* (2009) reported in correlation studies that the per cent fruit infestation had significant positive correlation with total sugars, potassium where as significant positive correlation with total sugars, potassium where as significant negative correlation with total phenols, copper, manganese, calcium and ash. The per cent shoot infestation had significant positive correlation with phosphorus, iron, magnesium, calcium crude fibre, ash and silica.

Genetics of various characters :

The knowledge of nature and relative magnitude of gene action (additive and non-additive) is of prime importance in designing suitable and effecient breeding programme for improvement of resistance and crop yield. The information on gene action for shoot and fruit borer resistance in brinjal was very meagre, as such, few scientists have worked on this aspect and which is reviewed below.

Singh and Kalda (1997) reported that the incidence of infestation in brinjal varieties from 30.5 to 39.9 per cent and thus concluded that susceptibility to *L. orbonalis* is a dominant character in brinjal.

Dhankar *et al.* (1979) evaluated four hybrids and their six parents, which differed in resistance to *L. orbonalis* and yield potential, for 12 yield related traits and 9 susceptibility characters. The hybrids BR-103 x White long and BR-112 x Aushey gave positive heterosis for marketable yield and tolerance. The susceptibility of hybrid obtained by crossing two tolerant types (PPL and Aushey) suggested that more than one recessive gene was responsible for controlling tolerance to *L. orbonalis*.

Dahiya *et al.* (1985) analysed a top cross involving 10 lines and 4 testers, the variance due to gca of females and males and sca of crosses were highly significant for character *viz.*, loss of yield, infested fruits, infested branches, larvae/fruit, dry matter and total sugar content of fruits. The parents of Annamalai and PPC-2 were best general combiners for most of the characters. The study of sca effects has shown that crosses with tolerant x tolerant and tolerant x susceptible parents will be better in the hybridization programme for obtaining desirable segregants.

Dominance gene action has been reported to govern plant spread (Bajpai, 1977). Vijaygopal and Sethumadhavan (1973) reported that erect type plants were dominant over spreading type and the plant spread is polygenetically controlled. Purple colour is dominant over green (Khand and Ramjan, 1954; Swamy, 1970; Choudhary, 1972; More and Patil, 1982; Gopinath *et al.* (1986). Expression of fruit colour is monogenic (Choudhary, 1972; More and Patil, 1982; Patil and More, 1983; Swamy, 1970) whereas Thakur *et al.* (1969) reported two gene in complement action to express fruit colour and Khapre *et al.* (1985) reported that interaction of 3 non-allelic genes are responsible for colour expression. The inhertiance of fruit colour was found to be controlled by two dominant complimentary factors P and D (Thakur *et al.,* 1968). Swamy (1970) reported that elongated fruit shape was dominant over oval.

Patil and More (1983) reported three genes while Nimbalkar and More (1980) observed four for fruit shape. Dharmagowda (1979) reported over dominance gene action for number of seed per fruit.

Nagai and Kida (1926) reported dominance of spines on fruit stalks of brinjal. Rangaswamy and Sundaran (1973) reported that expression of spines is monogenic as also reported by Khan and Ramzan (1954) whereas Sinha *et al.* (1966) observed that inheritance of spines was digenic and explained it on the basis of duplicate dominant gene action.

Additive gene action governed the expression of fruit weight (Peter and Singh, 1973; Singh *et al.*, 1979; Sindhu *et al.,* 1980; Dixit *et al.*, 1984; Singh and Mittal, 1988).

Fruit diameter was governed by both additive and non-additive gene action (Singh and Mittal, 1988), fruit circumference has been reported to be governed by the additive gene action (Dixit *et al.*, 1984).

Ingale and Patil (1997) reported non-clustered fruiting to be dominant over clustered fruiting and suggested that the four complementary genes were involved; they also reported that purple pigmentation and presence of pubescene were dominant over green colour and absence of pubescence. Segregation analysis indicated that the purple pigmentation was controlled by four genes and presence of pubescence in the pedicel was controlled by three and four complementary genes in the fruit and flower, respectively.

Inheritance of yield in *S. melongena* was studied where in fruit yield and fruits/plant showed negative dominance effects. Duplicate epistasis was noted for these characters (Chadha and Sharma, 1989). Additive-dominance and digenic epistatic models explained the variation of yield components. Most characters were governed by both additive and non-additive gene effects, suggesting that a breeding strategy involving biparental mating and reciprocal recurrent selection would be the most suitable (Chadha and Sharma, 1991).

Additive gene action has been reported to govern inheritance of yield contributing characters in brinjal (Gill *et al.*, 1976; Sharma, 1985; Madalageri *et al.*, 1986; Naulsri *et al.,* 1986; Ranhawa, 1987; Kumar and Ram, 1997).

Non-additive gene action has been reported by Padmanabham and Jagadish (1996). Additive gene action governed the average fruit weight (Singh *et al.*, 1982; Dixit *et al.*, 1984; Mittal *et al.,* 1976; Peter and Singh, 1973; Salehuzzaman and Alam, 1983) whereas Dharmagowda (1979) reported both additive and dominant gene action for the average fruit weight.

Kathiria *et al.* (1998) found both additive and non-additive components were important for fruit weight. Additive gene action has been reported to govern number of fruits per plant (Gill *et al.*, 1976; Singh *et al.*, 1979; Salehuzzaman and Alam, 1983; Randhawa, 1987; Singh and Mittal, 1988; Chadha and Sharma, 1991). Dixit *et al.* (1984) reported inheritance of number of fruits per plant to be governed by both additive and non-additive gene action.

Shinde (2006) reported that the epistatic components were involved in the expression of most of the chemical characters in brinjal fruits. Both additive and non-additive gene effects should be exploited by using different breeding approaches and back crossing with the genotypes having low sugars, phenols, nitrogen and silica levels in brinjal fruits.

Shinde (2007) reported that the additive, dominance epistasis and gene effects was important for most of the characters in brinjal shoots. It should require to be exploited these gene effects through different breeding approaches and back crossing with the genotypes having higher crude fibre, ash and silica levels in brinjal shoots.

Shinde *et al.* (2009) studied the nature and magnitude of gene action in six generation mean for resistance to shoot and fruit borer related characters in four crosses in brinjal. Study indicated that magnitude of dominance effected was higher for almost all the character except per cent infested shoots, fruits length, pedicel length, days to 50 per cent flowering and fruit skin thickness. Epistatic component additive x additive, and dominance x dominance was involved in the expression of most of the characters. Duplicate type of epistaits was observed for most the crosses.

It is therefore, suggested that while selecting genotypes for shoot and fruit borer, apart from their performance based on per cent, heterosis and association of morphological, physical characters due consideration may also be given on content of each biochemical parameters in fruits and shoots of brinjal. These characters may be considered while selecting the genotypes for further improvement in brinjal in relation to resistance to *Leucinodes orbonalis* Guen.

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