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Factors imparting resistance against the fruit and shoot borer *Leucinodes orbonalis* guenee infestation in brinjal crop- A review

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Abstract
Brinjal, is an important solanaceous vegetable crop in the tropical and subtropical region which is sufficient in different essential elements. However, the production is threatened with several losses due to different factors. Amongst those, the shoot, and fruit borer (BSFB), *Leucinodes orbonalis* is one of the most limiting factors. The infestation of BSFB may result up to 70% of losses in brinjal across India. In vegetative phase, the caterpillar bore into terminal end of stem to the calyx. The caterpillar bore into young fruits through the fragile calyx tissue, leaving no clear evidence of infestation. Some eggplant varieties have distinct biophysical (viz., plant height, fruit shape, plant structure, fruit length, spines of leaves, fruit size, branches per plant, petioles, fruit skin width, calyx of fruits and shoot thickness, etc) and biochemical features (viz., moisture, sugars, mineral material, overall phenol, ash content, silica, etc) that Impart long term resistance of Brinjal shoot and fruit borer (BSFB). Long thin fruited brinjal cultivars were observed to be less damaged than circular fruited cultivars because the larvae bore more efficiently in round fruits. In a BSFB resistance breeding programme, the cultivar with the low calyx and pedicel, the low sugar, the high phenol and the high polyphenol oxidase, were used to develop a resistant cultivar. Genetic improvement in crop could also be utilized for resistance development in the brinjal crop. Expoitation of resistant genes (additive and non-additive) is very crucial to achieve an effective and well-organized breeding plan to improve resistance and crop production by combating this pest attack.

Keywords: *Solanum melongena* L., *Leucinodes orbonalis* guenee, resistance cultivars, biochemical, biophysical and genetic factor

Introduction

Solanum melongena L., commonly known as brinjal or eggplant or aubergine, is an important solanaceous vegetable crop in the tropical and subtropical regions of India [41]. Eggplant is cultivated throughout the year under irrigated conditions, and it is commonly consumed by people around the world [36]. It is rich in proteins, nutrients, minerals, vitamins, and antioxidants [25, 28]. Hundred grams of raw brinjal fruit, contains 92.3 g water, 25 cal, 0.98 g protein, 5.88 g carbohydrates, 2 mg sodium, 0.18 g fat, 0.081 mg copper, 44 mg sulphur, 229 mg potassium, 9 mg calcium, 52 mg chlorine, 0.23 mg iron, 14 mg magnesium, 2.2 mg vitamin C, 24 mg phosphorus [45]. Eggplant is widely cultivated in Bangladesh, France, China, Pakistan, India, Philippines, Japan, Italy and United States, the highest brinjal production recorded, within 7 countries, viz., India, Japan, Iran, Turkey, China, Indonesia, accounting for 93% of total output, with a production of 10.50 million tonnes, it is produced on approximately 18, 47, 787 acres, or around 37 percent of the world's Eggplant area [12]. China is leading in its production (56 %of global output), followed by India (26%), with India producing 12.5 million tonnes per year and covering 0.67 million hectares [5]. Different biotic factors are responsible for India's low eggplant production. Among the biotic factors, insect pests severely harm the crop.

More than 36 different pests' species have been reported to attack on brinjal crop in the field [34]. Brinjal shoot and fruit borer (BSFB), brinjal stem borer, beetles, leaf roller, jassid, aphids, mites, white fly and thrips are some of the primary pests of the brinjal crop in India [20]. Among these primary pests that infest the crop, BSFB is one of the most destructive one, causing crop yields losses of up to 70-80% across India [26]. It is also harmful to potatoes and other members in the solanaceous family. This insect is active throughout the year in areas with a moderate climate, however it is negatively affected by extreme cold. It is known to harm shoots and fruit of brinjal at all stages of the crop development [7]. Synthetic insecticides are considered to be the most effective tools against BSFB, but their indiscriminate use may result in pest resurgence, which causes serious problems including pest resistance at vegetative & reproductive phases of crop development, respectively and pesticide residue can cause environmental pollution [15], they are an exceedingly detrimental to human health because the crop is a staple and most preferable vegetable that is consumed in its natural condition [16]. To combat these issues, host plant resistance is an ecofriendly approach, and can be used with other control methods like chemical, cultural, and biological control [29].

Resistant cultivars of brinjal can be administered which can be an important component in bio-intensive pest management strategy.

Owing to devastating nature of *L. orbonalis* various varieties of *Solanum melongena* L. have been tested against this pest having distinct biochemical and biophysical features that improve long-term resistance to BSFB [23].

Insecticides are used continuously and indiscriminately, resulting in increasing selection pressure, which leads to the development of pesticide resistance [39], that's why farmers used host plant resistance and IPM for pest control.

Failure in insecticide resistance and subsequent control resulted from the indiscriminate use of different insecticides compel to find some sustainable management approach. This review focuses to highlight the parameters which can lead to the host plant resistance against shoot and fruit borer attack in brinjal

Methodology

The information for this review article was obtained from related thesis, review reports, books, survey reports, and research papers, and other related available published sources.

Mode of Injury and symptoms caused by BFSB

The damage caused by brinjal shoot and fruit borer begins soon after the seedlings are transplanted and continues until the fruits are harvested. Single eggs are laid on the ventral surfaces of leaves, flower buds and shoots as well as on fruits [32]. The overall life span of this pest was reported to range between 25.06 to 36.72 days and breeds 10 time per year with a fecundity vary from 38.20 to 74.60 according Singla *et al.* (2018) [40]. Studies revealed that the male to female ratio of about 1:2 and actual fecundity and potential fecundity per female ranges from 123 and 207 eggs, respectively [2], which can indicate a fast and rapid growth in the population under suitable condition. Laboratory studies reveal that EFSB, *Leucinodes orbonalis* will complete its life cycle in 28.17 days. Patel *et al.* (1988) [31] studied the population dynamics with weather parameters and found that, BSFB biology will be fluctuated very little with minimum and maximum temperature, high relative humidity, although the impact of heavy rain is more on the population dynamics and all these parameters boost the population of BSFB.

On fruits/units, developing parts, and inflorescence, BSFB mostly targets the blossoming, fruiting, and vegetative development stages [6]. BSFB larvae bore into the closest delicate shoot, flower, or fruit within one hour of emergence. They attach or plug off the passageway opening (nourishing passage) with their excreta after drilling into the shoots or fruits [3]. A single BSFB larva can cause damage to 4-6 healthy fruits [4]. Damage to the fruits may give rise to secondary infection by certain bacteria resulting in the rotting of the fruit and rendering it unfit for marketing and human consumption [17].

Eggs of fruit and shoot borer

Bored hole near the calyx

Bored hole plugged with excreta of BSFB Larval stage of BSFB feeding inside the fruit

Fig 1: Infestation and damage symptoms of BFSB from field samples.

From the fourth week of October to the second week of December, a larval population excreta were seen on different cultivars' products; however, the larval population on fruits was related to the most extreme and least extreme temperatures [37]. Few field symptoms of infested brinjal have been collected from field survey of the attack of BSFB (Fig. 1) at LPU campus agricultural plot which showed the major infestation was near peduncle and fruits.

Screening of wild and cultivated brinjal varieties for resistance against BSFB

The screening studies indicates a range of resistance found in different cultivars and its wild relatives. Three wild brinjal species, *S. incanum*, *S. khasianum,* and *S. viarum*, were shown to be resistant to fruit infection by BSFB, with fruit infestation range from 0.5 to 10% [42].

Researchers from different areas have focused to find some resistant source to combat this pest incidence. Out of different screening experiments conducted, the brinjal varieties viz., Pusa purple long, BR-112, Pusa Kranti, Black Beauty, Pusa purple cluster and Neelam long [47]; Muktakeshi, Jamki-1, Islampuri-3, Jamki-2 and BL-34 [24]; Katabegun WS, and Marich begun [1] Sweta and Ravaiya [11]; Dil Nasheen [36]; in Bangalore and Pant Samrat [10]; BH-3 were the cultivars that were less destructed by BSFB [35].

Physical and Biochemical Characteristics

For effective use of resistant sources in crop development programmes, knowledge about the mechanisms of resistance and related factors are required. Plant morphological traits, as well as chemical contents, play a key role in providing insect resistance by making plants less appealing to insects, as these characters interfere with oviposition, development, mobility and feeding of the insect. Moisture, sugars, mineral material, overall phenol, ash content, silica, etc are chemical properties. Plant height, fruit shape, plant structure, Fruit length, spines of leaves, Fruit size, Branches per plant, petioles, fruit skin width, calyx of fruits and shoot thickness, rough fibre and other physical attributes of eggplant fruits and shoots are generally used to determine BSFB resistance in brinjal.

Physical characteristics/factors of Resistance

Amongst different morphological characteristics, the number of short, styled flowers per plant, number of long styled flowers per plant, fruit weight, number of fruits per plant, days to first harvesting, and BSFB incidence were all observed to have significant positive direct effect among the sixteen morphological features studied. Amongst all the physical parameters studied, it was observed that the fruit weight and fruit girth had a positive and significant correlation with the number of fruits per plant [43].

Accoriding to Sridhar *et al*. (2001) [42] the occurrence of this pest was shown to be lower in cultivars with comparatively long fruits and hardly arranged seeds. CHB-187, 259 and CHB-103 were discovered to be truly safe cultivars under (Bhubaneshwar) conditions between them cultured lines. The hybrids with an intermediate growth pattern (semi-spreading), predominant spines on both leaf surfaces, stem, on the calyx and petiole demonstrated a very resistant reaction to BSFB infestation [30]. Hazra *et al.* (2004) [14], observed that the thick terminal shoots, large and wide calyxes, and plump, heavy fruits were shown to be highly correlated with susceptibility to BSFB infestation. Javed *et al.* (2011) [19], discovered that in the brinjal genotype, have a very strong and negative correlation between insect population and leaf trichomes (r= -0.821), stem thickness (r = -0.819) and stem hair density (r = -0.807), respectively. Wagh *et al.* (2012) [46], observed that the shoot thickness and percent shoot infestation in brinjal against BSFB infestation have a strong and positive correlation (r =

0.632). Prasad *et al.* (2014) [33] observed that fruits with a round, green, and oblong shape were more resistant against BSFB infestation. Furthermore, the mean length of the fruit and fruit width showed a non-significant but negative correlation with BSFB infestation. Challa *et al.* (2021) [8], observed that the pericarp thickness (r = 0.89) has a substantial positive correlation with fruit infestation, but trichome density (r = 0.89) has a significant negative correlation with fruit infestation. BSFB resistance was found in brinjal hybrids with shorter pedicel length, longer fruits, single-colored fruits and smaller fruit girth [44].

Biochemical Characteristics/factors of Resistance

Jat and Pareek (2003) [18] found to be positively associated of total sugars, crude protein, and free amino acids with fruit infestation, while the total phenols have been found to be negatively associated. Shoot damage, on the other hand, was found to be negatively correlated with silica content. Fruit susceptibility to BSFB infestation was negatively correlated with total phenol content [14]. The genotype ABSR-2, which produced the highest yield, had the less quantity of shoot and fruit damage, the less calyx and pedicel, the less sugar, the highest phenol, and the highest polyphenol oxidase, might be utilized as a resistant cultivar in the BSFB resistance breeding programme [27].

Another comparison between ten genotypes of eggplants, showed some correlation with nutrient factors and the infestation level. They concluded the nitrogen (r=0.69), crude protein (r=0.68), and moisture (r=0.84) contents in fruits have positive and significant correlations, whereas tannin (r=-0.85), total sugars (r=-0.67), fibre (r=-0.76), and phenol (r=-0.80) contents had significantly negative correlations with percent fruit infestation by BSFB [9]. Khorsheduzzaman *et al.* (2010) [21], It was discovered that among five eggplant genotypes, less susceptible genotypes had higher levels of lignin, phenylalanine ammonium lyase (PAL) and polyphenol oxidase (PPO), as well as lower levels of reducing sugar in their shoots and fruits. Percent infestation of shoot and fruit was found to have a significant negative correlation with lignin, PAL and PPO content, but a positive correlation with reducing sugar content. All these finding gives us a clear idea about the strong negative correlation of different biochemical parameters and BFSB infestation, which can be exploited for breeding studies.

Genetic manipulation of various characters coferring resistance against BSFB

Incorporation of resistance trait by genetic manipulation is another tool to use for making insect resistant hybrids. Either we can use the IPM module or HPR or genetic advancement. Nature's information and gene activity are critical in developing a proper and well-organized breeding programme for resistance and yield development. In the early years, there was relatively less knowledge on gene action for BSFB resistance in brinjal, so a few scientists worked on this aspect, which is reviewed below.

By cocultivation cotyledonary explants with Agrobacterium tumefaciens, a synthetic cry1Ab gene coding for an insecticidal crystal protein (ICP) of Bacillus thuringiensis (Bt) was transferred to eggplant. Kanamycin-resistant transformant plants were regenerated. Bt toxin protein expression was detected in transgenic plants using a double-antibody sandwich ELISA. The transgenic brinjal fruits have a significant insecticidal action against BSFB larvae because of the expression. The results also revealed that a synthetic gene for insect control based on monocot codon use can be produced in dicotyledonous plants [22]. Hautea *et al.* (2016) [13] observed that the Cry1Ac protein levels in plants were measured in field trials, and their efficiency against the major target pest, BFSB, was assessed. Bt eggplant lines have shown to be effective against BFSB. For all field efficacy parameters tested, pairwise analysis of means revealed highly significant differences between Bt eggplant lines and their non-Bt equivalents. During experiment 2, Bt eggplant lines demonstrated high levels of control of BFSB shoot and fruit damage (98.6–100%), as well as reduced BFSB larval infestation (95.8–99.3%) under the most severe pest pressure. Moths produced no viable eggs or offspring when they emerged from larvae collected from Bt plants in the field and reared in their Bt eggplant hosts. These results indicate that Bt eggplant lines containing Cry1Ac event EE-1 have good BFSB control and can significantly reduce the use of conventional insecticides.

The finding of this papers reveals that introduction of this crystal protein gene as shown resistance against BSFB. These types of technology can be incorporated in upcoming era for controlling BSFB.

The nature and magnitude of gene action in six generations of brinjal crosses for resistance to BSFB related characters except for percent infested shoots, pedicel length, fruits length, days to 50% flowering, and fruit skin thickness, the magnitude of dominance impacted was larger for practically every attribute studied. In the expression of most of the characters, epistatic components additive x additive and dominance x dominance were involved [38]. Different eggplant genotypes exhibit a lot of genetic variety, according to a molecular analysis using random amplified polymorphic DNA (RAPD) has proved it. Resistant genotypes accumulated with higher levels of defensive biochemical enzymes such as solasodine, phenylalanine ammonium lyase (PAL), polyphenol oxidase (PPO), PO and phenols, which imparted insect resistance. Scientists suggested that, in the future, these genotypes, specifically genotypes IC411485 and IC090951, could be used as different parents in breeding programmes to create enhanced BSFB resistance lines [8].

Conclusion

Apart from the use of chemicals and other potentially hazardous methods for the control of BSFB, it is essential to utilise pest resistant cultivars that have been evaluated by many researchers and scientists for the control of pest attacks. Many other techniques, such as cultural control, physical control, and natural enemies, can also be used to improve pest prevention methodologies. The research findings on different factors indicates high potentiality which can be explored in near future. The focus should be given more in exploitation of inbuilt heritable characteristics from wild relatives of brinjal and should be incorporated in new breeding lines. Genetic manipulation of incorporation of genes which can help in conferring resistance against this major pest is the need of hour. Apart from their execution in light of heterosis, and relationships of morphological, physical characters, it is advised that consideration should be given to the content of each biochemical parameter in brinjal fruits and shoots when selecting genotypes for BSFB, so for successful control of BSFB, the cultivars having that resistance traits should be chosen for cultivation for controlling this pest in a sustainable manner.

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