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REVIEW PAPER OPEN ACCESS

Accessing resistance against fruit and shoot borer (*Leucinodes orbonalis Gune.)* infestation in brinjal (*Solanum melongena* L.). - a review

Ihtisham Ul Haq[1*], Amir Latif[2], Waqar Ahmad Khan[1], Asif Latif[1], Haram Aziz Alvi[1] and Muhammad Najeebullah[2]

Department of Plant Breeding & Genetics, University of Agriculture, Faisalabad

[2]Vegetable Research Institute, Ayub Agricultural Research Institute, Faisalabad

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Abstract

Brinjal (*Solanum melongena* L.) is one of the most important vegetable of Asian continent and having India as its center of origin. The major cause of importance is its high medicinal values i. e. curing cancer and as well as nutritional values e. g. good source of antioxidants. During whole cropping season brinjal faces many stresses and insect pests. One of the most important insect pests causing damage to both productivity and quality of brinjal is shoot and fruit borer (*Leucinodes orbonalis Gune.)*. A single larva can damage as many as 6 fruits by boring into shoot and fruit causing 60%-70% reduction in yield. Many breeding approaches have been utilized to screen out germplasm having resistance against its insect pest. All available germplasm was screened out to look for resistant traits. Various morphological and biochemical traits have been identified that were associated with resistance to insect infestation. Many wild relatives of crops that have been identified carrying resistance against this insect pest that can be utilized in breeding programs. One the most popular technique of development of transgenic crops can also utilized to develop *Bt* brinjal carrying *Cry1Ac* toxin that cause death of shoot and fruit borer by disrupting its midgut. This review carries all breeding and biotechnological concepts and approaches to develop resistance against this dangerous insect pest.

* **Corresponding Author:** Ihtisham Ul Haq ✉ 2015ag6303@uaf.edu.pk

Introduction

Brinjal (*Solanum melongena* L.) also has various names according to respective regions like eggplant in North America and Australia while aubergine in UK cultivated for edible fruit and used as vegetable. It is an important crop in many countries like China, India, some European and several African countries (Lovelock, 1972). Vavilov (1951) suggested Indo-China as its center of origin. It is cultivated on more than 1.8 M hectares of area across the world. Out of the total world production (52.3 M Tonnes), only Asia continent is producing (49 M Tonnes) which is equal to 92%. In world, China is the top producer (32.9 M Tonnes) comprises more than 62% production of the total. While various countries contribute in remaining production i. e. India (12.5 M Tonnes), Egypt (1.3 M Tonnes), Turkey (0.88 M Tonnes) and Pakistan only (88 Tonnes) (FAOSTAT, 2017).

Brinjal is a good source of minerals, vitamins, proteins, fibers and antioxidants (Gopalan *et al.,* 1996; Obho *et al.,* 2005). Brinjal's fruits have various health benefits (Ames *et al.,* 1993; Hung *et al.,* 2004; Khan, 1979) and ranked among top vegetables due to presence of flavonoic constituents and fruit phenolic contents (Timberlake, 1981; Singh *et al.,* 2009).

Fruits also have high hydrophilic oxygen radical absorbance capacity that prevents from damage caused by these free oxygen radicals (Cao *et al.,* 1996). Presence of phenolic compounds is also observed including delphinidin as a major part of fruit's peel (Wu *et al.,* 2006; Koponen *et al.,* 2007) while chlorogenic acid is of fruit's flesh that works as antioxidant (Winter and Hermann, 1986; Whitaker and Stommel, 2003). Brinjal extracts have medicinal values. Due to presence of strychnine and anthocyanins these extracts can be used in various diseases treatments like cancer, high blood pressure, and hepatosis (Silva *et. al.,* 1999; Magioli and Mansur, 2005).

Brinjal crop faces many biotic and abiotic factors viz. heat stress, diseases etc. that contribute towards lower yield. Major biotic factors include insect pests. These insect pests degrade quality and also affect highly crop productivity by direct attack on crop. Among various pests, fruit and shoot borer (*Leucinodes orbonalis Gune.)* is the major insect pest of brinjal in Asia (Sardana *et al.,* 2004; Rahman, 2006). Hemi (1955) reported that the infestation of fruit and shoot borer reduced Vitamin C contents upto 68% in attacked fruits. Khuhro *et al,* (2011) told in Pakistan, fruit infestation is varied between 6.6%-46.6percent. Cork (2004) showed that fruit infestation is more than 80% in Bangladesh northern and areas of India. Mall *et al,* (1992) also reported infestation rate upto 60%. On the other hand, during rainy season this pest is very active and can cause more than 90% damage in South East Asian countries (Kalloo, 1988; Krishna *et al.,* 2001). Mall *et al.* (1992) contemplated fruit and shoot borer disastrous for the brinjal.

Now, there is dire need to address this issue to overcome constraints occurring in both yield and quality related parameters of Brinjal by utilizing all possible breeding resources to create resistance against infestation of fruit and shoot borer in brinjal.

Mode of Fruit and Shoot Borer Attack

The life cycle of fruit and shoot borer varies between 26 days-39 days with 10 generation within a single year (Lall and Ahmad, 1965). A single individual can lay upto 267 eggs (Patel and Bose, 1948). Pests start feeding on young stems and switch to fruits when shoot becomes tough and thick (Lall and Ahmad, 1965). Alam and Sana, (1962) reported that larvae of this insect bore into petioles and young stems of brinjal. After entry, it closed down the entry hole by its excreta and feed on shoot tissues while residing inside plant. In later stages, it bored into fruit through calyx without showing any visible sign of entry and started infestation.

The infested shoot dropped off due to disruption of plant vascular system. The infested flower buds dry out and shed. High shoot infestation indicates that fruit infestation will also going to be high (Panda *et al.,* 1971). Butani and Jotwani, (1984) also reported same mechanism for brinjal fruit and shoot borer infestation. Jayaraj and Manisegaran, (2010) reported that larva of fruit and shoot borer can damage many shoots and 4-6 fruits single handedly. The loss in yield is accounted between 30%-70% due to this pest (Lall, 1964; Mishra and Mishra, 1996; Singh and Kalda, 1997; Kumar and Shukla, 2002).

Conventional breeding approaches

The most convenient way from many decades that is still popular, collection of available germplasm from all available resources. Then, look for variation among the available germplasm and exploitation of that variation in future breeding programs for improvement of crops. While taking brinjal under consideration many, breeders evaluated various available genotypes against fruit and shoot borer infestation (Sharma *et al.*, 1985; Dilbagh *et al.*, 1991; Jyani *et al.*, 1995). Mishra *et al,* (1988) tested 46 brinjal varieties to access resistance against fruit and shoot borer.

Some long-fruited varieties showed resistance to fruit and shoot borer infestation. Various morphological features associated with resistance. But some varieties carrying same morphological characters showed susceptibility towards infestation. With the passage of time and domestication of crops resulted in narrow genetics base in modern cultivars. But, even with narrow genetic bases there is sufficient variation present among population that can be utilized for crop improvement (Duvick, 1984; Rasmusson and Phillips, 1997). Darekar *et al,* (1991) reported some biochemical components are associated with resistance to fruit and shoot borer attack.

Kumar *et al,* (2008) utilized various phenotypic traits for screening of germplasm viz., Number of primary branches, Fruit weight (g), Number of fruits/plant,

Fruit width (cm), Fruit length (cm), Fruit peduncle length (cm), Days from transplanting to first fruit set, Days from transplanting to 50% flowering, Leaf blade width (cm), Leaf blade length (cm), Petiole length (cm).

Introgression through wild relatives

Plant domestication is an evolutionary process in which wild types of crops have been altered according to the need that resulted in narrowing down of the genetic base of the crop. Due to continuous selection process, only fewer genes are inherited to next generations. These crops carrying narrow genetic background are more susceptible to both biotic and abiotic stresses. Wild relatives of crops are distributed across the globe except Antarctica and most of them located in center of origins suggested by Vavilov and along their regions as well (Maxted and Kell, 2009; Larson *et al.*, 2014; Castaneda-Alvarez *et al.*, 2016). Global distribution of these wild relatives creates a clear opportunity to use them in breeding programs. They will be good resource for crop improvement due to their broad genetic base. Maxted and Kell, (2009) suggested that 10,739 species have values for food security. Global warming expected to have broad range of environmental effects i. e. shift in weathering patterns and rise of new diseases and insect pests that will have direct impact on crop productivity and growth (Tester and Langridge, 2010). Several studies showed importance of crop wild relatives and there utilization for future breeding processes (Zamir, 2001; Colmer *et al.*, 2006; Hajjar and Hodgkin, 2007; Maxted and Kell, 2009; Nevo and Chen, 2010; Ford-Lloyd *et al.*, 2011; Porch *et al.*, 2013; Warschefsky *et al.*, 2014; Brozynska *et al.*, 2015; Redden *et al.*, 2015). Some efforts are made to exploit diversity residing inside wild relatives for improvement of crops (Tanksley *et al.*, 1996; Hajjar and Hodgkin, 2007; Nevo and Chen, 2010; Maxted *et al.*, 2013).

Resistance against fruit and shoot borer in Brinjal has been found in its wild relatives. Lal *et al,* (1976) reported that five wild types of brinjal viz., *S. sisymbrifolium*, *S. xanthocarpum, S. nigrum, S. Khasianum and S. integrifolium* were resistant to shoot and fruit borer attack while *Solanum incanum* showed small percentage of infestation between various years. Dhankar *et al,* (1977) showed *S. sisymbrifolium* as resistant to shoot and fruit borer in ratoon crops. Kale *et al,* (1986) announced *S.*

incanum, S. Khasianum, S. Xanthocarpun and S. sisymbrifolium to carry resistance against shoot and fruit borer.Baksha and Iqbal (1979) announced field resistance in *S. Macranthum, S. Incanum, S. mammosum and S. khasianum*. Tejavathu *et al,* (1991) proposed *S. gilo* and *S. manomalum* as resistant to *L. orbonalis*. Singh and Kalda (1997) detailed *S. gilo* and *S. Manomalum* to have high resistance from fruit and shoot borer. Gangopadhyay *et al,* (1996) detailed that *S. incanum* was resistant to shoot and fruit borer infestation. These all reported wild types are vital resources to breed new varieties or hybrids resistant to shoot and fruit borer.

Morphological and Biochemical Factors of Resistance

Morphological and biochemical phenomena are the chemistries behind the resistance process against any type of stress e. g. increase in relative water contents during drought stress is the factor that indicates drought tolerance in plants (Schonfeld *et al.,* 1988) and Proline accumulation is indicator of plant is surviving under environmental stress (Rhodes *et al*., 1986; Delauney and Verma, 1993; Kishor *et al*., 2005; Verbruggen and Hermans, 2008). Same goes for biotic resistance like plant texture and biochemical constituent of crop. Chandrasekhar *et al,* (2009) reported various morphological traits of brinjal viz., thickness of pericarp and mesocarp have significant positive relation to resistance against fruit and shoot borer and genotypes having compact seed rings showed less infestation.

On the other hand, biochemical like tannins and phenols have significant negative relation with shoot and fruit borer infestation. High conc. of phenols averted insects due to its toxicity. Genotypes having high phenol conc. reduce the infestation rate and impart role in resistance (Asati *et al.* 2002; Jat and Parrek, 2003; Chandrasekhar *et al.*, 2008; Elanchezhyan *et al.,* 2009; Prasad *et al.*, 2014). Polyphenol oxidase has high negative relation with infestation (Doshi, 2004; Khorsheduzzaman *et al.,* 2010). Doshi, (2004) proposed Glycoalkaloids and solasodine have negative correlations with fruit and shoot infestations.

Transgenic Brinjal (Bt brinjal)

Bacillus thuringiensis is a gram-negative type of bacteria whose crystal protein toxin *Cry1Ac* is utilized as bio-insecticide. *Cry1Ac* toxin has specific activity against lepidopteran insects (Schnepf *et al.*, 1998). *Cry1Ac* toxin is reservoir of insect pest resistance in genetically modified crops. To make insoluble crystal toxin soluble, alkaline digestive tract is necessary (Dean, 1984). These soluble toxins digest cell membranes and make pores in gut. As fruit and shoot borer is a serious threat to brinjal productivity, transgenic brinjal carrying *Bt* gene can be utilized as resistant approach towards its infestation. Pal *et al*, (2009) developed transgenic brinjal using *Bt* gene. Gene is retrieved from National Research Center for Plant Biotechnology (NRCPB), New Delhi, India and transformed into inbred line of brinjal through *Agrobacterium*-mediated gene transfer. Furthermore, hypocotyls are the most efficient explants having transformation frequency of 17.3% per explant. Conformation of single copy of gene in seven independent plant is done by PCR and Southern Blot analysis. It is further confirmed by segregation analysis of T1 seeds from T0. Quantitative ELISA showed presence of significant levels of *Cry1Ac* toxins in leaf samples (2.46-4.33 ng/ml). When larvae fed on plants showing high expression of *Cry1Ac* toxins resulted in significant mortality rate.

Kumar *et al*, (2011) showed brinjal hybrids carrying *Bt* gene were consistently more yielding in comparison of brinjal hybrids without *Bt* gene. The yield of *Bt* hybrids was 37.3% more than non-*Bt* hybrids (same genotypes that were transformed) and 59.4% more than popular hybrids. In the same way, lower level of shoot infestation was observed in *Bt* hybrids (0.24 %) as compared to check (4.64 %) and non-*Bt* hybrids (4.86 %).

Bt brinjal resulted in lower chemical insecticide utilization. Less utilization provided farmers with health benefits restraining from direct exposure to chemicals (Krishna and Qaim, 2007; 2008). These highly varied factors among *Bt* and non-*Bt* are indicators that *Bt* brinjal is a handful technology in creating resistance against fruit and shoot borer infestation.

Conclusion

Many evidences have been provided that there is sufficient level of variation present among the various genotypes of modern cultivar and landraces. Crop wild relatives' also have resistant traits against insect pests and these traits can be corporated in our modern cultivars through breeding efforts. Genetically modified organisms (GMO) is a handy protocol for creating resistance against these insects in crops. All these procedures are purely breeding and biotechnology based.

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