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THE IMPACT OF TRANSGENIC BRINJAL FOR THE CONTROL OF *LEUCINODES ORBONALIS* GUENEE AND POSSIBLE EFFECTS ON NON-TARGET ARTHROPODS: A COMPREHENSIVE REVIEW

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ABSTRACT

Brinjal (*Solanum melongena* L.) is the most important vegetable crop in the Asia Pacific region, with Pakistan being the seventh largest producer. There are many biotic and abiotic factors affecting its production in terms of quantity and quality including insect pests as a significant constraint. In Pakistan, the brinjal shoot and fruit borer, *Leucinodes orbonalis* is the major insect pest of brinjal. However, some other chewing and sap-sucking insects are also essential pests. *Bt*-brinjal, a transgenic variety, has been introduced in India and Bangladesh for the management of lepidopteran pests. Before the commercialization of transgenic brinjal in Pakistan, it must be assessed for its effects on the environment and non-target organisms. This study is presenting the overview of transgenic brinjal as an option to manage brinjal shoot and fruit borer along with current and future challenges in areas of its commercialization.

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INTRODUCTION

Developing countries of Asia like Pakistan, India, Africa and Bangladesh need a continuous increase in food production. This increase is only possible with increased per unit yield from the existing land and natural resources available for food products, including cereals, fruits and vegetables (Sharma et al., 2000). For an increase in per unit yield of food crops, minimization of pest-associated losses is a practical approach which is reported up to 14% of total agriculture production (Oerke et al., 2012).

Brinjal is one of the most important and nutritious vegetable, available all around the year in the market at

a reasonable price. The increasing demand for brinjal, importing countries are focused on quality production without or with reduced use of insecticides. China is the largest brinjal producer country in the world, with 34 million tons of annual production. In Pakistan, 87,000 tons of brinjal are produced annually from an area of 9,000 hectares (GOP, 2019). Insect pests are the major biotic factor to reduce its yield and quantity, including brinjal shoot and fruit borer, brinjal stem borer, whitefly, jassid, thrips, mealybug and mites. Only brinjal borer is causing 78% shoot damage and 66 to 90% of fruit damage with severe yield losses (Muhammad et al., 2020a; Reddy and Srinivasa, 2004; Singh and Singh,

2000). Farmers are mostly relying on pesticide use for the management of brinjal pests like many other crops. These chemicals are destroying environmental and human health, along with lowering the immunity level against infectious diseases (Muhammad et al., 2020b). There are many other options to control pest levels including crop rotation, weeding, destruction of alternate host plants, mulching, clipping, biological and legislative control measures and introduction of transgenic crops (Ahmad et al., 2020). This article is focusing on the scope and challenges of *Bt*-brinjal varieties introduced for managing the pest pressure and reduction of pesticide use.

Data Collection

In this review article, information was collected from the research articles, critical reviews and different database search engines. The facts were compared with pesticide use and *Bt*-toxin incorporation in pest control programs.

***Bt* Protein in Brinjal**

Bacillus thuringiensis (*Bt*) is a Gram-positive bacterium found in almost all types of soils which may be activated when crystalline proteins (Cry proteins) are reached high pH areas of insect midgut. These proteins have insecticidal properties and may be utilized through different modes of entry (Höfte and Whiteley, 1989; Kumar et al., 2011; Shelton, 2010). *Bt* toxins are not contact poisons like other insecticides but can kill insects when reaching to their midgut through feeding (Ninfa and Rosas-García, 2009). Brinjal shoot and fruit borer expresses the required characteristics to be controlled by using *Bt* toxins.

Availability of *Bt*-Brinjal

Bt-brinjal known as "*Bt* talong" cultivar has been developed in the Philippines and released for farmer's cultivation long ago and it was also designed in India and Bangladesh in 2010 and 2014 respectively. *Bt* brinjal varieties are available with their different brand names in their countries of production. Bangladesh Agricultural Research Institute (BARI) has reported a positive response of farmers with reduced insect damage and higher yields. In Pakistan, *Bt* brinjal has not been cultivated till now. Organic farms are already using *Bt* toxins as foliar sprays instead of insecticides, and plant produced *Bt* toxins are safer for non-target organisms.

Effectiveness against *Leucinodes Orbonalis*

Bt brinjal has effectively controlled the brinjal shoot and fruit borer due to the larvicidal activity of cry1Ac protein. Bangladesh has approved four different *Bt*

brinjal varieties for the management of brinjal shoot and fruit borer in 2013 (Koch et al., 2015). Anderson et al. (2019) reported the effectiveness of *Bt* brinjal against brinjal shoot and fruit borer in India, Bangladesh and the Philippines. It was strongly suggested to adopt *Bt* brinjal for reduction of high use of insecticides against brinjal shoot and fruit borer (Choudhary and Gaur, 2009). The effectiveness of *Bt* brinjal was reported along with its safety to natural enemies, human and environmental health and other non-target organisms. Farmers are increasing interest to adopt *Bt* brinjal because its economic returns are higher than conventional varieties (Shelton et al., 2018). *Bt* brinjal can be successfully incorporated in IPM programs against brinjal shoot and fruit borer (Mark et al., 2001). Prodhon et al. (2018) studied different isolates of *Bt* and their non-*Bt* brinjal cultivars for their effectiveness against brinjal shoot and fruit borer. The results revealed that *Bt* brinjal isolines were enough to control the pest completely, and the number of insecticide sprays were remarkably reduced, and crop yield was increased. According to this study, about 27000 farmers are cultivating *Bt* brinjal to avoid pesticide use on directly consumed vegetables by a human.

Safety for Non-Target Organisms/Human Health

Different studies conducted on *Bt* brinjals and normal brinjals showed that *Bt* plant material has no negative impacts on soil microbes and plant pathogens present in the soil (Anderson et al., 2019; Donegan et al., 1996; Palm et al., 1994). It was also revealed that the *Bt* plant material does not prevail in the soil for long periods and breaks down in necessary plant materials. *Bt* technology is the safest tact to control target pests only without any resistance development mechanism (Donegan and Seidler, 1999; Mendelsohn et al., 2003; Sims and Holden, 1996). *Bt* brinjals are proved safe in the studies of their pollen flow and crossing back programs. These were also against the rats and had no acute oral toxicity or primary skin irritation in rabbits (Kumar et al., 2011). These toxins are also reported safer for Sprague Dawley rats, Brown Norway rats, common carp, New Zealand rabbit, broiler chickens, goats and lactating crossbred dairy cows. *Bt* brinjal varieties have also performed better in the field and showed higher yield as compared with non *Bt* varieties. Moussa et al. (2018) has reported that *Chrysoperla carnea* reared on *Bt* maize feeding aphids did not show any negative response on their lifetable parameters. Romeis et al. (2019) has informed the *Bt*

brinjal is safer for biological control agents. There was a myth about *Bt* corn that it is responsible for causing human allergy after consumption of *Bt* corn and when it is grown for animal feed. Later studies by the disease control center refused this and reported other than *Bt* toxins (Séralini et al., 2007). The net conclusion from all tests and reports suggested the use of *Bt* brinjal is safe for human health.

Resistance Development Issues

The studies regarding resistance development against *Bt* toxins have shown different responses in different insect pests. *Bt* brinjals have not yet demonstrated any effect of resistance in brinjal borer. Noctuid insects have shown resistance in field experiments against the *Bt* toxins (Matten et al., 2008). *Spodoptera frugiperda* has also demonstrated resistance development to *Bt* corn after 4 years of continuous feeding. Stem borer of maize has shown resistance to *Bt* corn after 8 years of cultivation (Kruger et al., 2009; Vanrensburg, 2007). *Helicoverpa armigera* has shown resistance to *Bt* cotton against Cry1Ac protein expression (Liu et al., 2010).

Sustained susceptibility has also been reported in eight different target insects against *Bt* cotton and *Bt* corn after long cultivation of 8 years (Tabashnik et al., 2009). It shows that there would be resistance management against *Bt* crops through the adaptation of different tactics like strip planting of non-*Bt* crops.

Controversies of the World

First *Bt* genes were introduced in soybean, canola, cotton and corn. Human beings did not directly consume these crops and concerns were highlighted about the environment and non-target organisms. The entry of the first genetically modified vegetable "*Bt* brinjal" was denied in India and still not in practice in Pakistan. The experts have proved that the declining population of monarch butterflies was not affected due to *Bt* corn pollen (Bravo and Soberón, 2008; Mark et al., 2001). Similarly, issue of *Bt* maize crossing with other grasses was also technically denied. Stunted growth of kidney was also reported free of *Bt* toxins (Kumar et al., 2011). The other main issue raised against *Bt* brinjal is the development of resistance in monophagous pests like brinjal shoot and fruit borer which should be addressed after proper research in brinjal growing areas (Deka and Barthakur, 2010). Overcoming all controversies, the Genetic Engineering Approval Committee (GEAC) has allowed the limited release of *Bt* brinjal in India with monitoring of resistance and human health issues.

Different Government agencies in the world have imposed a ban on *Bt* crops which is discussed below. *Bt* maize was banned from importing and cultivation by the Hungarian government in 2005, followed by the European Union (James, 2016; Schmidt et al., 2009). *Bt* Cotton production was also banned by the progressive farmers of Africa. Russia imposed a ban on the import and cultivation of *Bt* plant materials in 2016. Many countries are allowing *Bt* crops on the condition of proper labelling during their sale in the market (James, 2016). The situation was worst for *Bt* crops when natural health authorities declared "Monsanto" as the worst seed company responsible for the release of *Bt* seeds (Gucciardi, 2011). These controversies are leading to the refusal of GMOs which need wide research and public awareness about the importance of *Bt* crops for pesticide-free vegetables.

CONCLUSION

Biotechnology, especially Genetically Engineered crops, are an essential tool for pest management and reduction of injurious pesticide use on crop plants. Plant-made toxins are a better option to control pests as compared with the injudicious use of insecticides. *Bt* brinjal cultivation has the potential to reduce pesticide use and increase production. The government must overcome the doubts in the minds of farmers and consumers for the encouragement of *Bt* brinjal. Adaptation of *Bt* technology in brinjal cultivation will increase production many-folds, and there will be no harmful effect on the environment, natural enemies, agricultural ecosystem and human health. The leaching off pesticide residues will also be reduced from the brinjal field and polluting the soil and underground water. Authorities have to conduct closely monitored studies on *Bt* brinjal cultivation and training of farmers to utilize the new pest management technique safer for human and environmental health.

AUTHOR CONTRIBUTION

All the authors contributed equally to collect and compile the literature and in its write-up. All the authors took part in its proofreading and editing.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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