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Climate change tolerant *Solanum melongena* development by inserting *cry1Ac* gene from *Bacillus thuringiensis*: some issues for policy concern in India

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ABSTRACT

Transgenic brinjal created by inserting cry1Ac gene from the soil bacterium Bacillus thuringiensis (Bt) into Brinjal can cope up with climate change conditions up to certain extent. Crossing Bt brinjal and untransformed brinjal can also produce hybrids. Genetically modified bringal shall be more insect resistant, high yields provider, more cost-effective and highly tolerant in adverse environmental conditions as climate change impact shall be minimal. Some important concerns about Bt Brinjal relate to its possible adverse impact on human health and bio-safety, livelihoods and biodiversity.

KEYWORDS climate change, Bt bringal, gene, crossing, transgenic

INTRODUCTION

The brinjal Solanum melongena is said to have originated in India and is known to have been cultivated for over 4000 years. The brinjal is a popular component of the Indian diet across the country. There are approximately 2500 varieties of brinjal in India of various shapes extending from oval or egg-shaped to long or clubshaped; and colours ranging from white, yellow, green and purple to nearly black. Across the world there are around 25 cultivated food species of Solanum, a genus of the nightshade family, or Solanaceae, which includes the potato, tomato and various eggplants [1]. The Report of the Expert Committee (EC-II) on Bt Brinjal submitted to the Indian government [2] described losses of between 60-70%, even when insecticides were used. Eggplant fruit and shoot borer (EFSB, Leucinodes orbonalis Guenée) damage in India lies anywhere between 5.3-54.8% of the total yield of crop. Losses vary considerably between the various Indian states and between climatic seasons, but seem to average out at around 30% [3].

Bt brinjal has undergone field evaluation by a national hybrid seed company in India [4-5]. One of the hazards arising from the introduction of genetically engineered (GE) crops into the environment is that associated with the integration and subsequent expression of the transgene (the genetic construct inserted into the GE plant genome) in a different species [6], as well as gene flow to non-GE forms of the crops. Since the 1980s, the realization that transgenes could move from cultivated crops to populations of their wild relatives has brought attention to the hitherto neglected area of crop to-wild gene flow [7]. Since the advent of GE crops such as Bt brinjal, GE cotton, maize, rice and soya into the environment, crop-to-wild gene flow research has grown [8-14]. S. melongena is believed to have originated in the Indian subcontinent [15-21].

More recently, based on the Botanical Survey of India, 48 species of Solanum in India are listed [22]. The brinjal is low in calories and fats and contains mostly water, some protein, fibre and carbohydrates. It is also an excellent source of minerals and vitamins and is rich in water soluble sugars and amide proteins among other nutrients. Genetic Engineering Approval Committee (GEAC), Ministry of Environment and Forests (MOEF), Government of India, deals with important issues in case of Bt Brinjal. Sustainability with respect to natural resources [23] have bearing on climate change [24].

METHODOLOGY

Transgenic brinjal plants, were developed, expressing cry1Ac gene isolated from Bacillus thuringiensis tolerant to the fruit and shoot borer (herein after referred to as Bt brinjal), one of the major pests which attacks the brinjal crop throughout its life cycle. The transformation was carried out using genetic engineering techniques viz. Agrobacterium tumefaciens mediated method. Bt brinjal contains three genes namely (i) the cry1Ac gene derived from Bacillus thuringiensis (Bt) to produce an insecticidal protein. The cry1Ac gene is driven by a viral promoter, the cauliflower mosaic virus (CaMV) 35S promoter; (ii) the nptII gene for an antibiotic resistance marker, neomycin phosphotransferase; (iii) the aad gene for another marker O-aminoglycoside adenyl trans ferase. One has to apply to the Genetic Engineering Approval Committee (GEAC) in the Ministry for environmental release.

Genetic engineering/modification involves artificial transfer of genes or gene fragments from one organism to another to produce novel traits in the recipient living organism. The steps involved in the development of a genetically modified (GM) plant are identification of a gene(s) giving a desired trait, designing genes for insertion, transfer to plant tissue, selection and regeneration of plants, lab analysis and safety testing, greenhouse and field trials, approval by Government agencies, commercialization and monitoring of efficacy and safety.

CHARACTERSTICS OF BRINJAL

The brinjal is usually self-pollinated. However, it has been reported that the extent of cross-pollination can range from 2% to as high as 48%. It is thus classified as a cross-pollinated crop. While the biological structure of the anthers favours self pollination, the stigma projects beyond the anthers, thus providing ample opportunity for cross-pollination. The genotype, location, and insect activity further determine the actual rates of natural cross-pollination. Pests affecting the brinjal crop include the brinjal fruit and shoot borer, the brinjal stem borer, the mealy bug, lace wing bug, leaf hopper, leaf rollers, red spider mite, leaf-eating beetle, jassids, aphids, white fly and root knot nematodes. Many of the hybrid varieties have shown a potential yield of upto 50 tonnes/ha. General concerns over transgene escape were incorporated into the Cartagena Protocol on Bio-safety to the Convention on Biological Diversity to which Bangladesh, India and the Philippines are signatories.

CROSSABILITY

The fertility links between species are noticeably reticulate. For example, S. incanum will hybridize with S. pubescens, S. violaceum with S. virginianum, and S. macrocarpon with S. aethiopicum. Moreover, S. melongena will hybridize with S. incanum, S. virginianum, S. violaceum, S. macrocarpon and S. aethiopicum. Interpretation of hybridization data has often been made difficult by erroneous identification of parent species, or nomenclature using outdated synonyms or rejected names. In many cases, a limited range of both S. melongena

and wild relative accessions was tested, often examining cross-ability in one (sometimes unspecified) direction only.

Full inter-fertility between species would thereby be indicated by crosses that fulfill this criterion in both directions. In investigating cross-ability and introgression potential between transgenic crops and wild relatives, some up-to date studies have examined a broad range of parameters. There has been considerable interest in the potentially damaging effects on plant biodiversity of the release of Bt brinjal. S. melongena itself is believed to form adventive populations that have diverged away from cultivated ones, and wild populations of brinjal are known to occur in India. A complex situation regarding inter-fertility, ferality and the potential for introgression of transgenes exists. There is insufficient evidence that non-GE brinjal will remain uncontaminated, and this risk needs to be evaluated.

CONCLUSIONS

Genetically modified species, through gene editing or cross breeding or any other methods, can be more tolerant to adverse environmental conditions and therefore better to cope up with climate change. Government must come up with improved policy with respect to genetically modified (GM) species/ crops for changing climate situations. The new techniques for understanding and modifying the genetics of living organisms have led to large investments in agro-biotechnology research and development. While Bt cotton is the only transgenic crop which is being commercially cultivated in the country, according to currently available information, 12 crops (11 of which are food crops) are under different stages of development. The focus of GM research in India is to develop crops that can withstand are (a) biotic stress: pest and disease resistance crops and management of weeds (b) abiotic stress: crops tolerant to flood, drought and salinity (c) product improvement.

Hybridization between Bt brinjal and some of its wild, weedy or cultivated relatives is likely if Bt brinjal is cultivated. Once such inter-fertility relationships are understood in more detail, we can then progress further in our evaluation of the risks to plant biodiversity. These relate to (a) wild or weedy relatives of brinjal obtaining selective advantage via transgene transfer from Bt brinjal, (b) wild relatives of brinjal suffering reduced genetic diversity from the introgression of the Bt transgene, and (c) introgression of the Bt transgene into non-GE brinjal.

It is important to note that when fruit and shoot borer larvae feed on Bt brinjal plants, they ingest the Bt protein Cry1Ac along with plant tissue. In the insect gut which is alkaline with a pH >9.5, the protein is solubilized and activated by gut proteases crystallizing into fine needle-like shards that pierce the insect gut lining making holes in it. This leads to disruption of digestive processes, paralysis and subsequent death of the fruit and shoot borer larvae. There has been much controversy over the reliability of such data, and this has been a major argument for withholding commercialization of the genetically modified (GM) crop in India.

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