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The long road to commercialization of Bt brinjal (eggplant) in India

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On 14 October 2009, the Genetic Engineering Approval Committee (GEAC) of India approved the commercialization of transgenic Bt brinjal (=eggplant), transformed to express an insecticidal protein (Cry1Ac) from the bacterium, *Bacillus thuringiensis*. This was a significant decision on the long road to becoming the first genetically engineered food crop in India. According to the Ministry of the Environment and Forests of the Indian Government, GEAC is the apex body constituted in the Ministry of Environment and Forests under 'Rules for Manufacture, Use, Import, Export and Storage of Hazardous Microorganisms/ Genetically Engineered Organisms or Cells 1989', under the Environment Protection Act, 1986 (http://moef.nic.in/modules/project-clearances/geac-clearance). Thus, the Minister of Environment and Forests, Mr. Jairam Ramesh, considers his agency as the final gatekeeper of genetically engineered crops in India. According to Mr. Vijayaraghavan, the South Asia Regional Coordinator of the Bt brinjal project, soon after GEAC's announcement, members of Greenpeace and other anti-biotechnology NGOs sent thousands of faxes and emails to Mr. Ramesh's office urging him to ban the cultivation of Bt brinjal. Thus, Bt brinjal continues to be caught in a political hurricane in India. Its final fate may be decided by the time this article appears in print, but what that will be is not presently known. I offer my perspective on this issue for your consideration. Much of the background on brinjal and its pest complex is summarized in a recent publication by Choudhary and Gaur (2009). However, this is only part of the story in this complex situation.

Brinjal, *Solanum melongena* (Family: Solanaceae), is a widely cultivated vegetable in India. Brinjal, along with tomato and onion, is the second most important vegetable in India and is considered the most affordable, so is consumed in a wide variety of dishes popular throughout India. Brinjal is highly nutritious and is believed to have certain medicinal properties and is culturally important to the Indian people who annually consume between 8 and 9 million metric tonnes which is grown on >500,000 ha. As with most solanaceous vegetables, brinjal has a diverse pest complex of insects and diseases, but the most serious is the fruit and shoot borer (FSB), *Leucinodes orbonalis* (Family: Pyralidae). As is typical with this insect family, preventing injury relies on the difficult task of using well-timed insecticide applications before the eggs hatch into larvae that bore into the stems or fruits of the plant. In India FSB causes yield losses of 60–70% even after repeated insecticidal sprays, resulting not only in significant crop losses but hazards to human health and the environment (Choudhary and Gaur, 2009).

For decades, scientists at the Asian Vegetable Research and Development Center (AVRDC) in Taiwan have worked to develop an integrated pest management (IPM) approach to control FSB. Talekar (2002) published a bulletin describing what he called a “Simple, Safe and Economical Approach” to controlling FSB. It relied on removing infested shoots and fruit, pheromone trapping to prevent mating, and judicious use of insecticides to protect natural enemies. To be most effective, he suggested that these practices be used on a community level since FSB can readily fly between fields. Although this integrated approach sounds reasonable, removing infested stems and fruits would lower yields and is labour-intensive. Additionally, pheromone disruption is often costly and does not provide the level of control needed. Thus, growers in India continue to rely on insecticides as their main method of control, spraying upwards of 40 times per season for control of FSB.

Insect-resistant plants (host plant resistance, HPR) should be the foundation of an IPM program (Naranjo et al., 2008); however, no high levels of resistance have been bred into commercially available brinjal varieties using traditional methods. If it had been, growers would surely have adopted them since they prefer to reduce labor

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and other input costs through effective and economical strategies such as HPR (Shelton, 2007). The development of insect-resistant genetically modified (IRGM) crops has expanded the availability of HPR germplasm and IRGM plants have become a major tool in IPM programs (Kennedy, 2008). A strong argument can be made that IRGM crops are simply another form of HPR, should be part of an IPM program, and will have the same benefits (e.g. reduced insecticide input) and risks (evolution of resistant insect strains) as traditionally bred resistant varieties (Kennedy, 2008). The first wave of IRGM plants to enter the market were those that express insecticidal crystal (Cry) proteins from the bacterium, *B. thuringiensis* (Bt). First commercialized in 1996, Bt maize and Bt cotton, the only IRGM field crops presently grown, were planted on 50.3 million ha in 2009 (James, 2010). With the adoption of Bt maize and Bt cotton, there has been a dramatic reduction in the use of traditional insecticides on these two important field crops. Brookes and Barfoot (2009) analyzed the global trends in insecticide use and reported that on a cumulative basis since 1996, 23% less insecticide active ingredient (ai) has been used (147.6 million kg) and that this resulted in a 23.8% reduction in the environmental impact (measured in terms of the Environmental Impact Quotient (EIQ)/ha; Kovach et al., 1992). For maize globally since 1996, 5.9% less insecticide ai has been used (10.2 million kg) and the EIQ has fallen by 6%. While Bt maize is not grown in India, Bt cotton is and its use has reduced the insecticide load. From 2002 to 2007, the cumulative insecticide ai use was 10.4% lower (18.9 million kg) and the total EIQ load was 9.7% lower (Brookes and Barfoot, 2009).

Maize and cotton seed oil are generally processed before entering the food chain for human consumption so these Bt crops have incurred perhaps less, although still considerable, concern about human safety. The only non-processed IRGM crop is the relatively small amount of Bt sweet corn (Burkness et al., 2002), which in 2008 constituted ca. 9% of the total fresh market sweet corn grown in the US. This situation will change dramatically if Bt brinjal is commercialized in India and Bt rice is grown in China (Bt rice was approved in China in the second half of 2009, http://www.stee.agri.gov.cn/biosafety/spxx/). I believe both of these events will be worldwide "game-changers" since together the population in these two countries, each over 1 billion, constituted 36.8% of the total world population of 6.7 billion in 2009 (http://www.internetworldstats.com/stats8.htm). If these IRGM crops become widely grown in China and India, they will likely open the gates for other GM crops in these and other countries. Greenpeace and other anti-biotechnology groups have lost battles against IRGM crops in many countries, but still have profound influence, especially in developing countries (Paarlberg, 2008). In China these NGOs lost the battle about Bt rice; in India they have put considerable resources into derailing the approval of Bt brinjal.

The transformation of Bt brinjal was first begun in 2000 by the Maharashtra Hybrid Seed Company (Mahyco) in India under a partnership with Monsanto and using its *cry1Ac* gene which had already been widely used in Bt cotton in India. Control of FSB by Bt brinjal was demonstrated in greenhouse trials and, in late 2003, a partnership was developed with Mahyco, Cornell University and the United States Agency for International Development (USAID) under the Agricultural Biotechnology Support Program II (http://www.absp2.cornell.edu/projects/project.cfm?productid=2). Each group shares in the responsibility to get Bt brinjal to market but what is unique is that the partners have decided to have two market channels: a "pro-poor" for the distribution of open pollinated (OP) lines and the "normal" channel through which the higher priced hybrid varieties would be sold and Mahyco would recover some of its investment. This pro-poor strategy and the shared partnership were particularly attractive to USAID which decided to provide funding to help the products come to market. The OP lines were created by local agricultural universities (e.g. Tamil Nadu) which received the donated original transformed line ("event") from Mahyco. As with any GM crop, the Indian regulatory system requires a set of studies which were carried out and these included: toxicity, allergenicity, animal feeding studies, pollen flow, food equivalency, non-target organisms, large-scale field trials as well as studies on the socio-economic impact of Bt brinjal. Additionally, an insecticide resistance management program and product stewardship program were required (many of these reports can be seen on the GEAC website, http://www.envfor.nic.in/divisions/csurv/geac/information_brinjal.htm). Many of the safety studies were made easier because of the familiarity with the *cry1Ac* gene which was approved in Bt cotton in India in 2002. In 2009, Bt cotton containing this gene was grown on 8.4 million ha in India (James, 2010). However, what is extremely advantageous to the commercialization of Bt brinjal is that India requires labelling only the seed packages as GM and not the final product. Labelling of the individual fruit in all the diverse marketplaces in India would have been impossible and was one of the strategies promoted by Greenpeace to halt Bt brinjal. Another Greenpeace strategy was to continue to bring lawsuits against large-scale field trials of Bt brinjal, and this strategy was successful in 2007 for several months before the Indian Supreme Court ruled in favor of allowing such trials. In 2008, Greenpeace mounted an aggressive campaign and projected Bt brinjal as a "Poison" product and Mahesh Bhatt, the film producer, created a movie called "Poison on the Platter" to highlight the harmful effects of GM foods in general and Bt brinjal in particular (http://www.wittysparks.com/2009/02/18/poison-on-the-platter-a-documentry-film/). Yogi Ramdev, a well know Yogic guru, also openly preaches against Bt brinjal (http://www.ayurvednews.com/archives/214).

On the other side, biotechnology has its supporters. The President of India, Smt. Pratibha Devisingh Patil, and the Prime Minister of India, Dr. Manmohan Singh, have both made statements about using biotechnology to meet the needs of the people of India. Most importantly, the data show strong economic and environmental benefits of adopting Bt eggplant. Krishna and Qaim (2008) analyzed field trials and surveyed eggplant farmers in the Central/South and East regions of India and estimated that the farmers' gross margins in these areas would increase by Rs. 16,299/acre ($361) and Rs. 19,744/acre ($437), respectively. They noted that yields of Bt hybrids were double those of non-Bt counterparts and, nationally, they estimated the aggregate economic surplus gains of Bt hybrids could be around $108 million/year with consumers capturing a large share of these gains. Furthermore, they stated that farmers will realize an additional $3–4 million per year in health benefits from the reduced insecticide sprays but that this is "only a small fraction of the technology's environmental and health externalities".

In the spiritual and diverse cultures present in India, the world's largest democracy, it is clear that the road to commercializing a GM product has had, and will continue to have, far more twists and turns than in other types of governments, such as China, which has decided to embrace food products produced through biotechnology to feed its citizens. In fact it has been argued that India adopted its first GM crop, Bt cotton, only after the farmers were faced with a crisis controlling the bollworm and threatened the Indian government with civil disobedience if it did not approve Bt cotton (Herring, 2007).

If and when Minister Ramesh approves Bt brinjal, it will not be the end of the road – it never is with any one tool of IPM. Although Bt brinjal has been shown to provide superior control of FSB, the key pest of brinjal, it is not the only pest. Other arthropods (mites, jassids, mealybugs, whiteflies and leaf eating beetles) and diseases (damping off, verticillium wilt, bacterial wilt, blights and rots) also must be managed. However, field trials submitted to GEAC by Mahyco have indicated that the amount of insecticides used against FSB was reduced by 80%, translating into an overall insecticide reduction of 42% for the crop (Krishna and Qaim, 2008). This would be a major achievement for the health and welfare of the people of India. As discussed by Naranjo et al. (2008), plants that are resistant to key pests should be the foundation for IPM. The question now is whether Bt brinjal will get through this last regulatory hurdle and whether educational programs can be implemented to help Indian farmers learn how to use this IPM tool to the advantage of the consumers, environment and their own agricultural sustainability.

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Epilogue

After this article was submitted for publication, on 9 February 2010 Minister Ramesh decided to impose a moratorium on Bt brinjal until "such times independent scientific studies establish, to the satisfaction of both the public and professionals, the safety of the product from the point of view of its long-term impact on human health and environment…." (http://moef.nic.in/downloads/public-information/Annex_BT.pdf). Reading through the entire document, it appears to me that the Minister was more strongly influenced by political pressure from those opposed to biotechnology rather than by critical scientific and balanced judgements of the technology. Despite his statement that his decision should not be construed as discouraging "on-going R&D in using tools of modern biotechnology for crop improvement" it is hard to conceive that such discouragement will not occur and have a profound negative impact on Indian agriculture. In the meantime, other Indian scientists and agencies are attempting to reverse the Minister's decision. Thus, at this time it is unclear what lies beyond the next bend in the road for commercialization of Bt brinjal in India.

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