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Agricultural Biotechnology Support Project II, South Asia

Supporting agricultural development through biotechnology

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Advancing Science for Safer Food and Environment

About ABSPII

The developing world can benefit from advances in biotechnology, but much needs to be done to make bio-engineered products available in forms that farmers can use. The Agricultural Biotechnology Support Project II (ABSPII) believes that farmers and consumers worldwide should have the opportunity to make informed choices about using bio-engineered products. ABSPII focuses on the safe and effective development and commercialization of bio-engineered crops as a complement to traditional and organic agricultural approaches in developing countries. The project helps boost food security, economic growth, nutrition and environmental quality in East and West Africa, Indonesia, India, Bangladesh and the Philippines. Funded by the United States Agency for International Development (USAID) and led by Cornell University, ABSPII is a consortium of public and private sector institutions.

The consortium develops innovative, pragmatic solutions, building on the successes of the Agricultural Biotechnology Support Project (ABSP) that was led for a decade by Michigan State University.

In South Asia (India and Bangladesh), ABSPII supports development of expertise in the areas of research, policy development, licensing and outreach to help reduce poverty and hunger through agricultural biotechnology. Current initiatives relate to development of Tobacco Streak Virus Resistant (TSVR) groundnut, Late Blight Resistant (LBR) potato, Fruit and Shoot Borer Resistant (FSBR) eggplant, drought tolerant rice and salinity tolerant (DST) rice.

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Message from the South Asia Regional Coordinator

ABSPII supported projects are conceived and executed to ensure sustainable impact to resource constrained farmers and global communities that are currently affected due to significant crop losses and environmental degradation. The fruit and shoot borer (FSB) menace has seriously eroded the sustainable income of the farmers growing brinjal due to intensive spraying of harmful pesticides, far beyond permissible levels. Over a period of time, the FSB has developed resistance to toxic pesticides requiring high dosages to be sprayed on successive days in order to mitigate crop losses. Despite heavy spraying, farmers tend to lose about half of their output to this pest. The brinjal is predominantly a variety driven crop, while hybrids have been gaining share over the recent years. The private sector has invested resources and developed a successful event for fruit and shoot borer resistance with the proven Cry protein that has been applied in millions of acres across various crops and around the world. With the application of the gene that has been found to be safe and stable over several years, the technology has a long history of safe application. However, ABSPII perceived that unless the public sector engages in addressing the needs of resource constrained farmers who are predominantly growing Bt brinjal varieties, the true benefit of technology will not be realized by low income communities. ABSPII has supported public sector partners to harness their capacity across the regions for a common cause. The collective ability of public researchers from institutions that are known for their excellent research and academic capability have contributed to the development of over twenty varieties that are popular in India, Bangladesh and the Philippines, the three key growing countries for brinjal.

Conventional management methods have not succeeded in mitigating FSB infestation in eggplant. The biotechnology tools have accelerated the breeding strategies with precision in gene transfer that can provide sustainable resistance to fruit and shoot borer. The proven technology has the potential to provide an additional income of over Rs.40,000 per acre to the farmer and help consumers access safe brinjals, free of toxic chemicals. The consumer today demands choice and the brinjals free of toxic chemicals will help the consumers to make that choice. Do we have a choice in denying the farmers the benefit of technology that has true potential to provide them sustainable income and the consumers a safe product to consume?

ABSPII partners are delighted that the fruit and shoot borer eggplant varieties that have been developed would bring immense impact to the farmers and consumers. This is a truly public partnership that has potential to set the example for several public partnerships. ABSPII recognizes the support provided by Mahyco, the private partner who has provided pro bono access to technology for public partners. The contribution of public partners in ensuring sustainable product application and in developing durable resistance management strategy is noteworthy.

ABSPII is delighted that the public partners will not just be engaged in developing the product but will be keenly associated in reaching the seeds to the resource constrained farmers. The seed multiplication and seed delivery capacity of the public partners will help to ensure highly cost effective access to technology and resultant benefits to resource constrained farmers. The public partners of ABSPII are committed to ensuring the execution of the seed delivery system to ensure accessibility by farmers in India, Bangladesh and the Philippines who currently do not have accessibility such technologies.

ABSPII partners have put their best efforts over the last six years in their commitment to take this initiative forward. The collective efforts of over 20 best-known scientists have gone into ensuring that only the best and safest products are delivered to the farmers and consumers. We are pleased to bring this edition of the newsletter that highlights the progress achieved by our partners in bringing gains to farmers and consumers through the development of safe and cost effective products.

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Bt Brinjal in India:Assessing Socio-Economic Benefits

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Bt brinjal, close to its commercial release in India has drawn immense attention the world over with both optimistic and mixed reactions. Being the first Bt vegetable crop in India and the first Bt brinjal variety in the world, various scientific trials, food and rigorous bio-safety examinations are being conducted to ensure the safety of consumers and the environment. In addition to the advantages of reduction in pesticide usage, minimization of yield loss and economic benefits, Bt brinjal has a significant role in improving the nutrition status of the masses, since it is one of the largest produced and consumed vegetables in the country. Beyond that, the success of Bt-cotton in the country further raises expectation for Bt brinjal by different stakeholders viz., farmers, consumers, policy makers and seed producers.

India is the second largest producer (after China) of brinjal in the world and contributes 26% of the global brinjal production. Brinjal is a versatile crop and it has been grown in the country under different agro-climatic environments. Area under brinjal was 55.67 lakh hectares (ha), 7.6% of total area under vegetables, during 2006-07 in India. This area has been growing at the rate of 3.10 per cent annually since 1993. Brinjal accounts for about 10% of the vegetable production in the country (93 lakh tonnes during 2006-07) and its production has been growing at the rate of 4.03% annually. Productivity of brinjal was 16.5 tonnes per ha during 2006-07 and it has been growing at the rate of 0.92% annually.

Brinjal is consumed in every part of the country by the people irrespective of their income. In India, per capita per day consumption of vegetables is only about 190 gm, which is 32 per cent less than the minimum dietary requirement of 280 gm per day per person. Brinjal is most affordable as well as nutritive vegetable with a low calorific value. It is a rich source of calcium, phosphorous, potassium, fibre, folic acid, sodium and vitamins B and C.

Why Bt brinjal?

Brinjal is largely cultivated by small and marginal farmers (1.4 million) in India, to an extent of 55 lakh ha (average of an acre per farmer) which ensures a reasonable income to them. Since 1980, more than 90 varieties and 30 hybrids have been released by the public sector research institutions and more than 25 hybrids by private companies in India. However, brinjal is prone to many insect-pests and diseases. Though brinjal hybrids have contributed to increased yield, they lack resistance to fruit and shoot borer (FSB) which is the most devastating. At the initial stage, FSB larva bores into tender shoots, feeds inside and then moves downward and destroys the growing points (Fig 1a). Even at the flowering stage, larvae feed on flowers leading to dropping of flowers and a reduction in fruit set. Later, at the fruit forming stage, larvae prefer to feed on tender fruits and deteriorate the quality (Fig 1b) as well as reduce the yield upto 60-70%. Once the larvae mature, they exit the fruit or shoot and descend to the soil for pupation. Infestation can continue until the last harvest and carried on to the subsequent season (Talekar, 2002; Talekar et al., 2003).

Fig 1a. *Larva bores into tender growing points*

Fig 1b. *Larva bored into the fruit*

To avoid heavy yield loss, farmers frequently spray insecticides and adopt biological measures to control/manage the FSB. In general, 15 pesticides are recommended on brinjal, out of which eight pesticides are being used for controlling FSB infestation. The larvae need to be controlled before they enter into shoots or fruits. After the entry, FSB remains inside and destroys both fruits and shoots and escapes insecticide sprays. The integrated pest management (IPM) strategies, pheromone traps and other traditional labor-intensive practices were found to be less effective. Hence, farmers seek alternate options and science offers a modern biotechnology instrument (Bt technology), which is considered to be very promising (Fig 2). The first generation of transgenic crops including Bt-cotton, corn and soybean that are resistant to specific pests and tolerant to herbicides have already been widely commercialized in several countries including India, where Bt cotton has been a great success (Choudhary and Kaur, 2009). Technically, Bt brinjal is developed in a similar way to that of Bt-cotton by the introduction of *Cry1Ac* gene, which expresses the Bt protein in all parts of the brinjal plant against the FSB.

Fig 2. *Bt brinjal prevents FSB infestation and bears quality fruit*

Research on the incorporation of the gene into the popular brinjal varieties and the fields trials are at the advanced level at several stations in India. Bt gene has been introduced into four popular brinjal varieties (Fig 3.) of Tamil Nadu and efforts are being made to develop and release Co2-Bt, MDU1-Bt, PLR1-Bt, and KKM1-Bt from Tamil Nadu Agricultural University at Coimbatore.

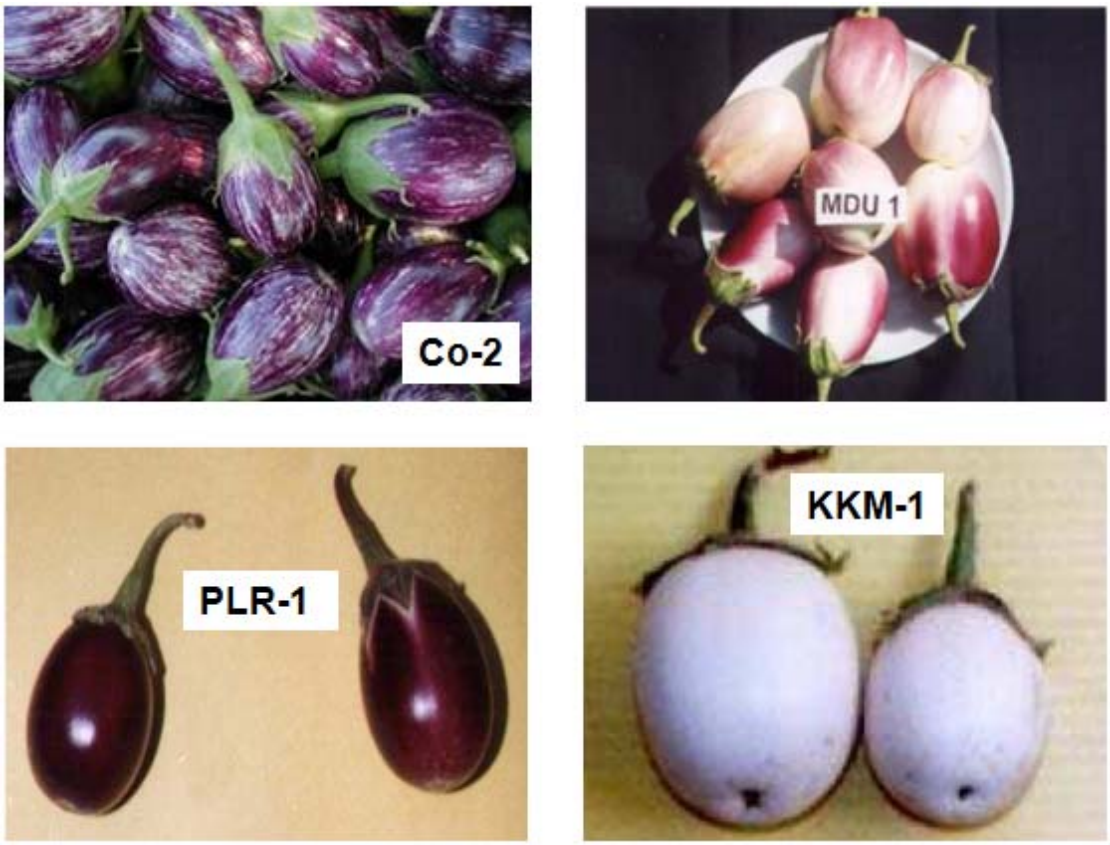

Fig 3. *Bt brinjal varieties developed by Tamil Nadu Agricultural University*

A detailed process for regulatory approval of Bt brinjal in India and time taken in completing different studies including laboratory experiments, greenhouse and confined field trials, bio-safety and food safety studies, multi-location and large-scale field trials for agronomic evaluation, and environmental impact assessment as well as the data generated from 2001 to 2008 has been made available on Genetic Engineering Approval Committee's GEAC website (http://www.envfor.nic.in/divisions/csurv/geac/bt_brinjal.html) for public information, scrutiny and comments.

Socio-Economic Benefits of Bt brinjal

Benefits from the Bt brinjal would flow into the hands of farmers, consumers and the seed producers. Since the Bt crop is on the edge of trials, the possible ex-ante outcomes were reported by several researchers. On the farmers' side, they would expect the benefits from the considerable reduction in unit cost of production (Fig 4) by reducing the cost of pesticides and hiring a sprayer. Krishna and Qaim (2007) reported a less unit cost of production due to reduction in pesticides spray, Rs. 147 per quintal of Bt brinjal while it was Rs.169 to produce a quintal of non-Bt brinjal. Total variable cost of growing the Bt brinjal would be Rs. 23,090 per acre, which is 29% higher than that of growing Non-Bt brinjal (Rs.17,897 per acre). Multi-location research trials confirmed that insecticide requirement for Bt brinjal hybrids was on average 80% less than for the non-Bt counterpart for the control of FSB; this translated into a 42% reduction in total insecticides used for control of all insect-pests in Bt brinjal versus the control. However, the gross income from Bt brinjal would be Rs.66,162 per acre due to higher yield. This would be 48.11% higher (due to seed cost, which was estimated from farmers' willingness to pay) than the gross income from non-Bt brinjal which accounted for Rs.44,670 per acre. Ultimately, Bt brinjal would result 60.88% higher gross margin (Rs. 43,072 per acre) as compared to non-Bt brinjal (Rs. 26,773 per acre). Comparison of cost and return from Bt and non-Bt crops is given in Fig 5.

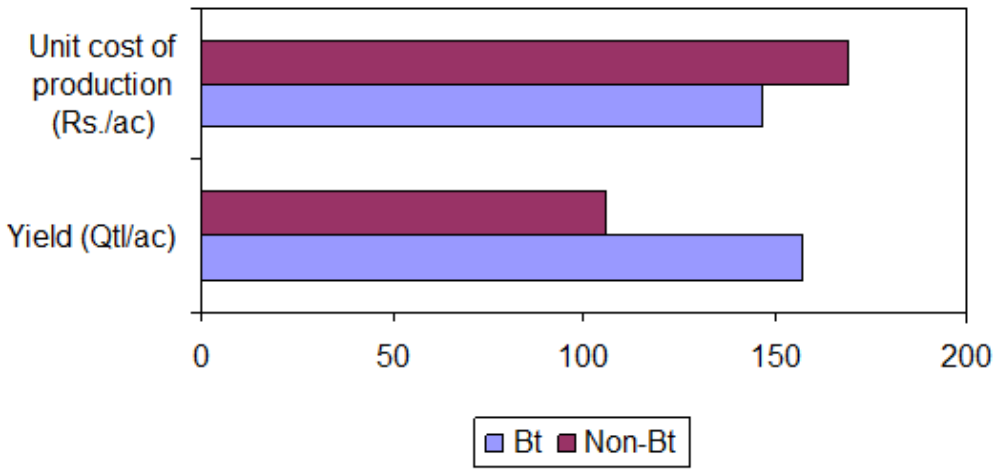

Fig 4. *Comparison of yield and unit cost of production between Bt and Non-Bt brinjal*

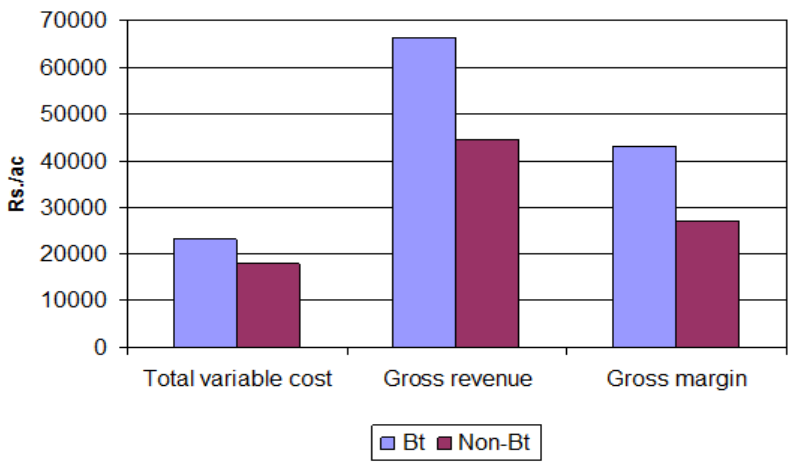

Fig 5. *Cost and returns from Bt and Non-Bt brinjal*

Based on the field survey (non-Bt) and the Mahyco field trials (Bt), a 40-60 per cent yield advantage of Bt over its Non-Bt counterpart was reported. Choudhary and Kaur (2009) reported a possible yield increase by 100% over its non-Bt counterpart hybrids, 116% over popular conventional hybrids and 166% over popular open- pollinated varieties (OPVs) of brinjal. However, these yield differences were observed under controlled laboratory/green house conditions and may vary under field conditions. The mean marketable yield increased by 25% and 31% compared to non-Bt counterparts and national best check under field trials. Hence, we adopt the lower value of the reported yield advantages (25%) to assess the income generation and price changes due to adoption of Bt brinjal at varying rates. There would be sliding prices due to the shift in supply at varying level of adoption. It is expected that Bt technology would cause price drop around 15% at maximum adoption rates. Adoption of Bt brinjal at different rates and consequent reduction in yield loss, which leads to increased output, price drop and income generation are illustrated in Table 1.

Table 1: Production, price and income benefits of adopting Bt brinjal

Adoption Rates (%)	Bt brinjal Area (X 1000 ha)	Productivity (Tonnes/ha)	Increased Production (Tonnes/ha)	Rice (INR/Tonne)	Additional Income (INR in Crores)
10	556.68	20.625	1148.15	6640.08	762
25	1391.70	20.625	2870.38	6572.67	1887
50	2783.40	20.625	5740.76	6404.14	3677

Initial adoption of Bt technology at the rate of 10% (5.5 lakh ha under Bt brinjal) would bring additional 11.48 lakh tonnes of brinjal, which would generate an additional income of Rs. 762 crores to the farmers. This increased supply would cause a slight drop (by 1.5%) in the price to Rs. 6640 per tonne from the existing average price of Rs. 6741.20 (average of 90 markets spread all over India (*Source*: agmarknet). Obviously, this benefits both the farmers and the consumers. The benefits will be manifold according to the rate of adoption as illustrated in Table 1 and Fig 6. There are indirect benefits like reduced hazards to human health and environment due to reduction in pesticides usage.

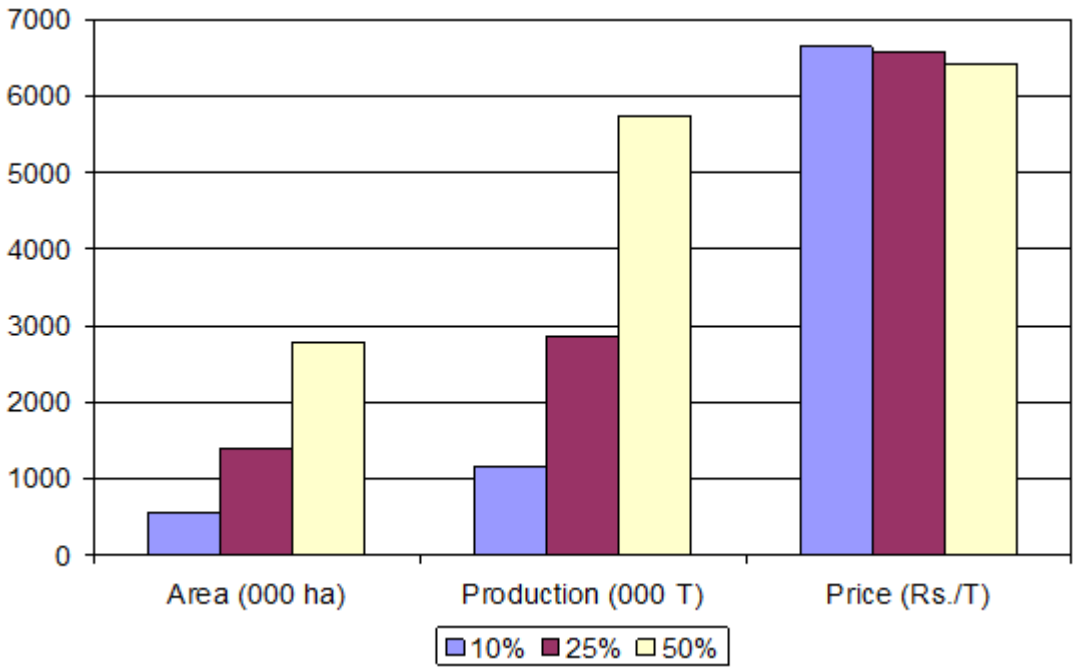

Fig 6. *Changes in Area, Production and Price of Brinjal under different rates of adoption*

Conclusion and Policy Implications

Bt brinjal effectively prevents the crop from the devastating FSB. Hence, brinjal would be produced at a lesser cost compared to non-Bt brinjal due to the considerable reduction in pesticides sprays as well as reduced yield loss. Bt is a supply shifting technology and would induce the price of brinjal to drop with increasing adoption rate. Effective Transfer of Technology and dissemination of facts and benefits of Bt brinjal would accelerate the rate of adoption thus benefiting both producers and consumers.

REFERENCE

Choudhary, B. and K. Gaur. 2009. *The Development and Regulation of Bt brinjal in India (Eggplant/Aubergine)*. ISAAA-Brief 38. No.38-2009.

Krishna, V.V. and Qaim, M. 2007a. "Potential Socio-Economic Impacts of Bt Eggplant in India", Chapter 5, the *Economic and Environmental Benefits and Costs of Transgenic Crops: Ex-Ante Assessment*, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu.

Talekar, N. S. 2002. *Controlling Eggplant Fruit and Shoot Borer-A Simple, Safe and Economical Approach*, AVRDC Publication Nos. 02-534, AVRDC, Taiwan.

Talekar, N. S. et al. 2003. *Development of an Integrated Pest Management Strategy for Eggplant Fruit and Shoot borer in South Asia*, AVRDC-The World Vegetable Centre. Technical Bulletin No. 28. AVRDC Publication No. 03-548.

Regulatory Pathway for Bt Brinjal: The Experience of TNAU

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One of the major constraints in brinjal cultivation is the damage caused by the brinjal fruit and shoot borer (FSB) pest. The loss resulting from this pest alone may be as high as 70%. Conventional methods of pest management are much less effective as the insect thrives deep within the fruit. This leads to indiscriminate spraying of insecticides by farmers to save the crop. In this process, the farmers spend a significant sum on pesticide sprays and simultaneously render the produce unfit for human consumption due to huge quantities of pesticide residue. Development of pest resistant lines is a major strategy for effective management of this pest.

A network of public and private institutions have been established with the support of Agricultural Biotechnology Support Project II (ABSPII) with the objective of making the fruit and shoot borer resistant (FSBR) transgenic brinjal available to resource-poor farmers through the trusted public system. The network comprises public institutions such as, Tamil Nadu Agricultural University (TNAU), Coimbatore; University of Agricultural Sciences (UAS), Dharwad; Indian Institute of Vegetable Research (IIVR), Lucknow; Cornell University, USA and the Maharashtra Hybrid Seeds Company (Mahyco), Jalna, India. This project is financially supported by ABSPII and DBT, Government of India.

FSB-resistant, open pollinated varieties of brinjal have been developed through the genetic background of region specific brinjal lines exploiting well-proven Bt technology. In this programme four elite genotypes were chosen as target genotypes in a back-cross breeding programme to introgress *Cry1Ac* gene from Mahyco's elite event, EE1. The local popular genotypes (Co2, MDU1, PLR1 and KKM1) were chosen keeping regional preferences in mind.

Bt brinjal contains a foreign gene, *Cry1Ac*, derived from a soil bacterium, *Bacillus thuringiensis* (Bt). This gene synthesizes a protein toxic to the fruit and shoot borer (FSB), a destructive insect pest. Its incorporation into brinjal confers the crop with 'built-in' resistance to FSB, reducing the reliance on sprayed pesticides. Mahyco has developed transgenic Bt brinjal technology. Mahyco brinjal genotypes were transformed with *Cry1Ac* using Agrobacterium-mediated method. An elite event was identified among the regenerated lines.

Mahyco's Bt brinjal hybrids containing event EE1 were evaluated under large scale field trials across the country. Besides efficacy studies and agronomic performance of these hybrids, biosafety analysis including pollen flow and effect on natural enemies has been done by Mahyco. The details of these studies are available in Genetic Engineering Approval Committee's (GEAC) website at http://www.envfor.nic.in/divisions/csurv/geac/geac_home.html.

The elite event, EE1 has been sub-licensed to public sector institutes such as TNAU, UAS-Dharwad and IIVR. Under this royalty-free license agreement, the public sector institutes will convert their elite brinjal genotypes into Bt open pollinated varieties (OPVs). Since the Bt brinjal has a varietal background, the farmers have the option of saving the seeds for future use.

As per the Environment Protection Act 1986, all GM products including Bt brinjal are regulated in India. To comply with the biosafety guidelines of the Government of India, TNAU complied with the following regulatory steps in the process of developing Bt brinjal OPVs which are in the pipeline for commercial release.

- The Institutional Bio-safety Committee (IBSC) of Tamil Nadu Agricultural University permitted the Department of Plant Molecular Biology and Biotechnology to carryout research on Bt brinjal in June 2004.
- IBSC recommended the transfer of transgenic brinjal material (F1s) expressing Cry1Ac from Mahyco in February 2005 to the Review Committee on Genetic Manipulation (RCGM).
- TNAU signed material transfer agreement with Mahyco for the transfer of Bt brinjal seeds in April 2005.
- RCGM permitted transfer of transgenic Bt brinjal from Mahyco on May 2005.

- With the approval of the RCGM, Dr. Usha Barwale of Mahyco handed over seeds of F1 Bt brinjal to Dr. C. Ramasamy, Vice-Chancellor of TNAU on 8 July, 2005.
- Back-cross breeding work was initiated in July 2005. All the subsequent works were carried out at the transgenic greenhouse facility, constructed to comply with biosafety guidelines of the Government of India.
- The progress of the programme and compliance of biosafety guidelines were submitted to the IBSC from time to time. The minutes of IBSC meetings and its decision were informed to the RCGM.
- TNAU proposed to conduct multi location research trials (MLRT) at the University research farms and submitted the application to the IBSC in its meeting held on May 9, 2007. The IBSC recommended the proposal and forwarded it to the RCGM.
- RCGM granted permission to conduct field trials in October 2007 to conduct MLRT in two locations.
- MLRTs on Bt brinjal were conducted at two places, Agricultural College & Research Institute, Madurai and Horticultural College and Research Institute, Coimbatore during October 2007 - May 2008. The progress of trials in these two locations was informed to the RCGM and the state government and district level officials. The trials were conducted as per the guidelines of the RCGM such as providing safe isolation, proper destruction of the produce, etc.
- A monitoring and evaluation committee comprising experts and officials from the state agriculture department constituted by the RCGM inspected these trials sites on 5 February, 2008 at Madurai and 10 April, 2008 at Coimbatore.
- At the end of the trials, plant remains were destroyed as per the guidelines and the field sites were monitored for any volunteer plants.
- The results of MLRTs were presented before the monitoring and evaluation committee on 22 July, 2008.

Results of these multi-location research trials indicate that the Bt brinjal OPVs offer adequate level of resistance to FSB and show potential for significantly higher marketable yield. Bt brinjal OPVs showed a significantly lower damage resulting from FSB feeding in comparison to non-Bt counterparts. Bt brinjal OPVs did not have any effect on non-target insects and beneficial insects.

Fig 5. *Monitoring and Evaluation Committee inspecting Madurai MLRT*

With the approval of the Government of India, TNAU is expected to launch Bt brinjal open pollinated varieties for commercial cultivation for the benefit of thousands of small and marginal farmers of the country during 2009. This product, besides benefiting the farmers and the environment, will also benefit the consumers by providing pesticide-residue free fruits.

Ensuring Safety of Transgenic Crops: The Case of Bt Brinjal

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Rationale for the development of Bt brinjal

The brinjal fruit and shoot borer (FSB) is the most damaging pest on brinjal crops, and farmers need to spray 25 - 80 rounds of pesticides during each growing season. Experts estimate that the financial loss to the country because of the 50 - 70% of damage caused by the FSB is equivalent to INR 1,000 crore per annum. As present control methods for FSB involve heavy pesticide sprays on the crop, brinjal produce potentially contains significant amounts of pesticide residues, posing health concerns for consumers as well as farm workers. Bt brinjal, a genetically modified (GM) or biotech crop, provides an alternative method for FSB control and pesticide application reduction. Field studies with Bt brinjal have demonstrated that farmers can use 70% less insecticide for FSB control and, as a result, 42% less pesticide overall for control of all insect pests. Field studies have shown that this results in an average 116% increase in marketable fruits over hybrids and 166% increase over open-pollinated varieties of brinjal. The higher yield and better quality would result in higher net income for brinjal farmers to the tune of Rs 16,000-19,000 per acre, which works out to Rs 2,000 crore to farmers throughout India.

Before any biotech food crop can be released into the environment in India, it has to undergo stringent biosafety tests, including environmental safety testing as well as food safety testing as mandated by regulatory authorities. This article describes tests conducted on Bt brinjal, which indicate that this crop is safe to the environment and safe for human as well as, animal consumption.

Germination and Weediness Studies

Germination tests demonstrated that there is no significant difference in the rate and/or time taken for germination between Bt brinjal and its non-Bt counterpart. Bt brinjal and its non-Bt counterpart did not differ in growth characteristics or vigour. These results demonstrated that there is no substantial difference between transgenic Bt and non-Bt brinjal with regard to their potential for weediness.

Aggressiveness Studies

A study was conducted to monitor the aggressiveness of Bt brinjal as compared to its non-Bt counterparts. This assesses any change in plant behaviour which could lead to the crop posing a risk to the environment. In the study, after complete harvesting of the Bt brinjal crop, the area under planting was left undisturbed for three months and irrigated on a regular basis to allow for germination of any seeds that might have remained in the ground after harvesting the main crop.

The data provides information on germination rates and aggressiveness of naturally shed brinjal seeds under field conditions in the plots where Bt and non-Bt plants have been grown. Any plants emerging are checked to determine the presence of the biotech trait. In the study conducted on Bt brinjal there were no brinjal plants observed to grow or germinate in the plot over the period of the study. The data suggest that there is no aggressiveness or weediness demonstrated by Bt brinjal plants.

Pollen Flow Studies—2 Locations

Pollen flow studies on Bt brinjal were conducted to determine the distance traversed by pollen from Bt brinjal plants, which was found to be 20-25 m. The majority of cross-pollinations occurred within a few metres of the Bt plot.

Effect on FSB, Non-Target Insects and Beneficial Insects

In controlled field trials, significant differences were detected between hybrids based on presence or absence of Bt gene. For FSB counts, significant differences were detected between Bt hybrids (containing *Cry1Ac* gene) and all three non-Bt checks. All Bt hybrids showed significantly lower numbers of FSB larvae. Differences were also measured between the Bt hybrid and non-Bt check hybrids for shoot damage to plants from FSB infestation. Percent damage to shoots was significantly lower for the Bt group as compared to non-Bt hybrids. The degree of such differences in FSB feeding damage between Bt hybrids and non-Bt hybrids was significant.

Observations were taken till completion of all pickings, for the presence of secondary lepidopteran pests, sucking pests and beneficial insects. No significant differences were noted between Bt hybrids, the non-Bt counterparts and checks in terms of incidence of sucking pests (aphids, jassids, whitefly) and beneficial insects (chrysopa, lady-bird beetle, spiders).

Results of these multi-location replicated research trials indicate that the Bt brinjal hybrids provide adequate level of tolerance to BFSB and show good yield potential, BFSB efficacy and marketable yield. Bt brinjal hybrids showed a significantly lower damage resulting from BFSB feeding in comparison to non-Bt brinjal. Bt brinjal hybrids did not have any effects on non-target insects, including beneficial insects, and therefore can play a positive role within integrated pest management strategies for sustainable brinjal cultivation.

Effect on Soil Microflora Studies

The effect of growing Bt brinjal in open field on soil microflora, residue of Cry1Ac protein and soil invertebrates was studied over a number of growing seasons and locations. It was clearly demonstrated that there were no differences between Bt and non-Bt plots vis-à-vis soil bacteria and fungal count both at the rhizosphere and the soil beyond the rhizosphere. After harvesting of the crop, residual Bt protein was found to be non-detectable in any of the soil samples tested.

Similar results in terms of bacterial and fungal populations were obtained from soil samples collected periodically from Bt and non-Bt brinjal plots. These findings demonstrate that Cry1Ac levels as determined through bioassays in soil samples was below detectable levels in soil samples collected from Bt brinjal plots. Further, microbial populations from Bt and non-Bt plots showed similar patterns.

Substantial Equivalence Studies

Compositional analysis of Bt and non-Bt brinjal fruit showed similarity in composition when major components like protein, carbohydrate, oil, calories, ash, nitrogen, crude fibers and moisture contents were analyzed.

A comparative study for the chemical composition of the tissues of brinjal plants was made using Bt brinjal (incorporated with *Cry1Ac* gene) entries and three non-Bt controls. The chemical composition was determined in the fruit, leaf, stem and root tissues of the brinjal plant. The data obtained in this study indicated that there were no appreciable differences between Bt brinjal and non-Bt brinjal groups in the chemical constituents of moisture, proteins, oil, ash, carbohydrates, calories for fruit tissue and nitrogen, ash and crude fiber contents in leaf, stem and root tissues.

Chemical Fingerprinting of Bt and Non-Bt Brinjal (Alkaloids)

Estimation of the alkaloid content in Bt brinjal in comparison with its non-Bt counterpart was done at the Indian Institute of Chemical Technology, Hyderabad. Assessment of the presence of alkaloids in Bt and non-Bt brinjal fruit was done by chloroform and methanol extraction method using chromatographic techniques. There were no significant differences in TLC and HPLC profiles of Bt and non-Bt brinjal fruit in chromatographic analysis for alkaloid estimation.

Acute Oral Toxicity Studies in Rats

Acute oral toxicity study of transgenic Bt brinjal was conducted at Intox Pvt. Ltd., Pune, India to assess the safety of Bt brinjal. Acute oral administration of transgenic Bt brinjal expressing Cry1Ac protein to Sprague Dawley rats at the

limit dose of 5000mg/ kg did not cause any toxicity. Proteins that are non-toxic by the oral route are not expected to be toxic by the dermal or pulmonary route.

Sub-chronic (90 days) Oral Toxicity Study in Sprague Dawley Rats

Subchronic oral (90 Days) toxicity study of transgenic Bt brinjal in Sprague Dawley Rat was conducted at Intox Pvt. Ltd., Pune, Maharashtra, India. Based on the findings of this study, the no-observed-adverse-effect-level (NOAEL) of transgenic Bt brinjal expressing Cry1Ac protein in Sprague Dawley rat, following oral administration for 90 days was found to be more than 1000 mg/kg body weight. This study demonstrates that Bt brinjal expressing Cry1Ac protein is non-toxic to the study animal by oral route.

Sub-Chronic (90 days) Feeding Studies Using New Zealand White Rabbit

Subchronic (90 days) rabbit feeding studies were conducted on New Zealand White rabbits at Advinus Therapeutics Private Ltd., Bangalore, India. The objective of this study was to compare the wholesomeness and safety of transgenic Bt brinjal containing *Cry1Ac* gene with control non-Bt brinjal. As per the findings of this study, it was concluded based on the health, growth and physio-pathological parameters analysed during the experiment that there were no significant differences between the groups fed with transgenic Bt brinjal containing *Cry1Ac* gene and control non-Bt brinjal fruit.

Sub-Chronic (90 days) Feeding Studies in Goats

Subchronic (90 days) goat feeding studies were conducted at Advinus Therapeutics Private Ltd., Bangalore, India. The objective of this study was to compare the wholesomeness and safety of transgenic Bt brinjal containing *Cry1Ac* gene with control non-Bt brinjal. As per the results of this study, it was concluded based on the health, growth and physio-pathological parameters analysed during the experiment that there were no significant differences between the groups fed with transgenic Bt brinjal containing *Cry1Ac* gene and control non-Bt brinjal fruit.

Feeding Studies on Fish

A fish feeding study was conducted at Central Institute of Fisheries Education, Mumbai, India using the common carp, *Cyprinus carpio*. The objective of this study was to evaluate Bt brinjal as a feed ingredient for common carp and to study the comparative growth and survival of fish fed with Bt brinjal. The study found that fish fed with Bt brinjal showed similar growth patterns to those fed with non-transgenic brinjal. Bt brinjal, non-Bt brinjal-fed groups were found to be statistically similar in terms of fish growth responses, and histopathological alterations.

Effect on Health of Broiler Chickens

A chicken feeding study was conducted at Central Avian Research Institute, Izatnagar, India. The objective of this study was to assess the impact of transgenic Bt brinjal expressing *Cry1Ac* gene on chickens, in terms of growth performance and nutrient utilization. Results of the present study showed that body weight gain, feed intake and feed conversion ratio did not differ among Bt and non-Bt treatments. Several blood biochemical constituents did not differ statistically due to dietary treatments including Bt and non-Bt brinjal incorporated diets. This study found Bt brinjal to be as safe as non-transgenic brinjal in terms of responses of chickens fed with diet incorporating the two types of Brinjal.

Feeding Studies in Lactating Crossbred Dairy Cows

Cow feeding studies were conducted at GBPUAT, Pantnagar, to assess the nutritional value of transgenic Bt brinjal fruit in comparison with non-Bt brinjal fruit in lactating crossbred dairy cows in terms of feed intake, milk production and milk composition and to determine if the Bt protein was detectable in milk and blood of lactating crossbred dairy cows fed on ration containing transgenic brinjal fruits. From the study it was concluded that the nutrional value of both transgenic and non-transgenic brinjal fruits were similar in terms of feed intake, milk yield and milk constituents without any adverse effects on the health of lactating crossbred dairy cows.

Food Cooking and Protein Estimation in Cooked Fruits

Cooked brinjal fruits are consumed in various forms in India. Cooking studies carried out at Mahyco included most of the forms in which brinjal fruits are consumed. Tender brinjal fruits expressing the *Cry1Ac* gene (henceforth referred to as Bt brinjal) were used in these studies to determine whether the Bt protein was present in the cooked fruits. Uncooked Bt fruits and non-Bt fruits were used as positive and negative controls respectively, for ELISA . The fruits were harvested and brought to the lab on ice and used in different cooking experiments. The protein extracts from these samples were used in ELISA for the detection of Bt protein. The Bt protein was undetectable in the cooked fruits at the first sampling time-point irrespective of the cooking method used (roasted, shallow-fried, deep-fried or steamed). The first sampling time-point was 5 min for roasted fruit and 1 min for the other forms of cooking. This study indicates that the Cry1Ac protein in Bt brinjal fruits is rapidly degraded upon cooking.

Socioeconomic Studies

A number of socioeconomic studies that have been carried out by academic groups such as those by Chong, and Krishna and Qaim, indicate a receptiveness of farmers to the technology, and the potential of Bt brinjal to increase farmers' welfare through insecticide reductions, and an increase in marketable yields of brinjal.

Developing and Field Testing of Bt Brinjal Varieties: The UAS, Dharwad Experience

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Brinjal is a staple vegetable in India. Over the years, a number of high yielding brinjal varieties and hybrids have been developed both by public and private organizations for cultivation. The local cultivars (landraces) of brinjal are still important and are relished by farmers and consumers owing to their special taste and culinary properties. A number of local brinjal types with typical phenotypes are popular among farmers in northern Karnataka, southern Maharashtra and the state of Goa. Certain preparations of local brinjal are known to last longer when compared to the high yielding hybrids.

One of the most important advantages of local brinjal types to rural India is that the preparations made out of them stay longer under normal non refrigerated conditions. Our initial survey indicated dominance of six local brinjal varieties across the target area. The six local brinjal cultivars viz., malapur local, majari gota, udupi gulla, rabkavi local, kudchi local and GO-112, are the popular varieties among cultivators and consumers.

A major constraint in brinjal cultivation has been the fruit and shoot borer (FSB), that targets the entire crop stand. Farmers expend considerable efforts and resources in controlling the deadly FSB using chemical pesticides. Often the control measures are futile and farmers resort to more than the recommended dosage of pesticides with frequent

sprays in the hope of harvesting undamaged fruits that fetch higher price in the market. It has also been observed that this indiscriminate spraying of multiple pesticides accounts for 60 to 80 sprays over a crop period of 4 months.The result is increased cost of cultivation, pesticidal food contamination and environmental pollution.

Though local brinjal varieties are generally known to be tolerant to pests and diseases, they are highly susceptible for FSB attack. All the six local cultivars were chosen with an aim to take the fruits of modern science and the spirit of public-private partnership for Bt brinjal conversion programme with the support from ABSPII and DBT, Govt. of India.

Salient Features of Selected Local Brinjal Cultivars for Bt Transgenic Conversion Programmes:

1. **Manjari Gota**: A popular genotype of the Southern Maharashtra. Semi-erect herb, ash green coloured woody stem, green leaved. Stem, leaves, calyx etc. are spiny. Fruit-solitary, round, white with purple streaks. Highly susceptible to fruit and shoot borer.
2. **Udupi Gulla**: Grown in coastal Karnataka. Erect herb, green coloured leaves and stem. Fruit-solitary, round, green with creamy patches at stylar end. Highly susceptible to fruit and shoot borer.
3. **Malapur local**: Popular genotype of Northern Karnataka. It is medium to semi-erect. Leaves and stem are green coloured. Fruit solitary, occasionally very small spines are seen, oblong, lustrous, green with broad purple stripes. The purple coloured stripes fade but luster does not fade during summer.
4. **Kudachi local**: Popular genotype of Kudachi belt of Northern Karnataka. Erect in growth, very small spines on calyx. Leaves-green, fruits-solitary, green round with pink and white stripes.
5. **Rabkavi local**: Grown in Rabkavi belt of Northern Karnataka and parts of Maharashtra. Erect plant, non-spiny. Fruits-solitary, very broad and purple striped.
6. **GO-112**: A popular genotype in Goa. Erect plant type, weak leaf blade lobing, violet midrib colour, leaves-green, non-spiny, fruits-round, purple black fruit.

Development and Field Testing of Transgenic Bt Brinjal Varieties

The *Cry1Ac* gene was transferred through a backcross breeding method into all the six local brinjal varieties. The donor of *Cry1Ac*, the EE-1 event developed by Mahyco, was crossed with local varieties and subsequently backcrossed with their respective recurrent parent till BC3F1 stage. The progenies carrying *Cry1Ac* gene were identified and used each time. The BC3F2 plants were tested for their field performance in four locations, in following combinations;

Group -I: Bt Malapur local, Bt Manjari Gota, Bt Udupi Gulla, Bt Rabkavi local, Bt Kudchi local, Bt Goa-112 and their non-Bt counterparts along with Aruna as national check

Group-II: Bt Goa 112, Bt Udupi Gulla and their Non-Bt counterparts along with Aruna as national check.

The entries in group-I were evaluated in three locations, viz., Zonal Agricultural Research Station, Kolhapur (Maharashtra), Agricultural Research Station, Gadhinglaj (Maharashtra) and Agricultural Research Station, Kallolli (Karnataka). Similarly, entries in group-II were evaluated at Zonal Agricultural Research Station, Brahmavar (Coastal Karnataka). All these multi location research trials (MLRT) were conducted with the approval of RCGM during 2008-09. Another trial is currently in progress at Krishi Vigyan Kendra (KVK), Margoa, Goa.

All the Bt local varieties and their non Bt counterparts were subjected to critical observation for level of expression of Cry1Ac protein, FSB infestation, occurrence of beneficial and non-target insects all through the trial period in regular intervals. Other agronomical observations including infestation of nematodes etc., were recorded and the economic benefits of the technology were calculated. The trials were regularly monitored by a team comprising subject matter experts with a trial in-charge person at each location. All government regulations for the the conduct of MLRT were ensured at all locations at all times. The Monitoring and Evaluation Committee (MEC) visited all the trial sites and submitted their report to DBT, Government of India independently.

Strategy for Seed Delivery through the Public System: Case of UAS, Dharwad

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Eggplant popularly known as brinjal is a very important vegetable crop of the family Solanaceae which is native to India. It is a delicate perennial crop often cultivated throughout the year. The fruits are botanically classified as berry and contain numerous small soft seeds which are edible. It is predominantly cultivated in southern and eastern Asia but is also popular in the western world. Production of brinjal is highly concentrated with 85% of the output coming from three countries -- China, India and Egypt. This is the most commonly used vegetable in India and grown in all the seasons.

It is well known that many pests and diseases affect the brinjal from seedling to harvest of the fruits. Among them, fruit and shoot borer (FSB) a major pest, destroys the fruits at all stages of development. The conventional approach to managing these pests is becoming cost prohibitive and non-eco friendly. Genetic modification using *Bacillus thuringiensis* (Bt) gene, which is detrimental to the soft bodied larvae has proved to be an effective pest management alternative. This Bt brinjal can be an economically and environmentally viable alternative technology for farmers to grow that would eschew the use of toxic and poisonous chemical pesticide sprays.

The most popular and preferred brinjal varieties of the consumers were identified for the southern states of Karnataka, Maharastra and Goa. The varieties included the malapur, manjari gota, kudchi local, udupi local. UAS-Dharwad in collaboration with ABSP-II incorporated Bt gene into these varieties supplied by Mahyco on a pro-bono basis. The product development work has been successful and is ready for commercial cultivation to the resource constrained farmers in South India at an affordable price.

The success of this initiative largely depends on the seed delivery system which is the final step in seed programme. Seed delivery is critically sensitive to time and other factors affecting rural marketing. Seed must reach the farmer at the right time, at the right place, at the right price, in the right amount and at the highest economic quality.

ABSPII strategy promotes a stewardship approach that includes product development, seed production, seed marketing and distribution, crop production, crop utilization, through to product phase-out. The overall aim of the stewardship approach is to maximize the benefits, and minimize any risk, from using the bioengineered products. Bt eggplant seed delivery program involves effective planning, coordination, team work, execution, proactive handling, close monitoring and risk mitigation. For this purpose, the all stakeholders need to be trained to handle this challenge. A comprehensive extension training manual need to be developed - at three levels - the first level at farmer education, the second level at the education of the distribution outlet (extension outlets and network centers that will be engaged in distribution of the seeds) and the third at the level of the extension professional.

Seeds of high quality is the prerequisite for the seed delivery system. UAS, Dharwad has identified four seed farms having efficient quality oriented production system for the production of quality seeds of identified four Bt brinjal verities. The seeds thus produced are brought to the seed unit which has the ultra modern facilities of complete drying, conditioning, treating and pouch packing systems. The seed quantity and research laboratory which ensures high quality seed along with safe storage and transport system to keep seeds in good condition.

To facilitate comprehensive tracking of all the processes that encompass the seed production-to-distribution process including Demand Forecasting, Production Planning, Seed Delivery, ABSPII has developed the Computerized Operation Tracing System (COTS) a Management Information System (MIS) that enables UAS, Dharwad to safely and efficiently ensure quality seed deliveries and aid in effective post-release monitoring of the Bt seeds.

Being a public system, the University can use its existing network stations to reach out to resource constrained farmers and those in remote locations thereby enabling round the year availability of high quality Bt seeds at affordable prices. The network stations will have a pool of ABSPII trained experts from the areas of plant protection, molecular biology, agronomy, and extension professionals who can disseminate the technologies to the field level. The package of practices (POP) in regional vernacular languages will be available as product literatures providing clear-cut guidance to farmers to fully utilize the technology. This will help farmers to quickly adopt these technologies ensuring faster acquisition of benefits.

The objective of the training program is to build capacity among the teams involved in the delivery process. Key training objectives would include:

- To provide an understanding of the steps involved in production of genetically modified food crops
- To sensitize on economic, environmental and social dimensions of commercial cultivation of Bt brinjal
- To sensitize the participants towards the process of market-oriented production and distribution
- To provide an understanding of the relevance of crop monitoring and its statutory requirements
- To make the participants understand and evolve the effective extension mechanism for promoting and delivering Bt brinjal seed.

The team would be drawn from different disciplines involving scientists from seed production to seed distribution. The program would include lectures, field visits and participatory discussions. The training program would include one in the main campus and four regional workshops to reach all the stakeholders of the entire supply chain. The stakeholders would include personnel at different levels, functions and locations. The successive levels will need higher level of exposure.

Simultaneously, awareness and benefits of the local Bt brinjal varieties will be carried out through careful planning and co-ordinated educational systems such as field demonstrations, field days, farmer training programmes and interface meetings through the well established network of agricultural research stations, *Krishi Vigyan Kendras* of the University and mass media tools such as newspapers, radio and television.

Development and Commercialization of Bt Brinjal: The Philippines Experience

ABSPII-Philippines FSBR Eggplant Team
ISAAA-South East Asia Center.

The eggplant, or the brinjal as it is also known, is an important crop both in South and Southeast Asia. In the Philippines alone, the brinjal is the leading vegetable crop with a cropped area of more than 20,000 hectares and total production of more than 190,000 metric tons. Based on the most recent retail price, the brinjal industry is valued at PhP 5.7 billion. The brinjal is an important cash crop to many subsistence farmers, and is known for its anti-oxidant and anti-stress properties.

The brinjal fruit and shoot borer (FSB) is the most damaging pest to the brinjal and can cause more than 50% yield losses in heavily infested areas in the Philippines. To control this pest, the farmers commonly apply insecticides to their crops as many as 70 times per cropping season. However, this practice adds up about 20% to the total production cost, in addition to the serious health and environmental hazards arising from heavy and indiscriminate pesticide use.

Recognizing the absence of conventional host plant resistance in brinjal commercial varieties and related germplasm, ABSPII paved the way for the biotechnology-based development of FSB-Resistant varieties in both South and Southeast Asia, especially in public sector plant breeding institutions. The Maharastra Hybrid Seeds Company, Ltd. (Mahyco) in India, a leading private sector seed company, pioneered the development and application of biotechnology for FSB

resistance, and served as principal technology developer and donor to public sector collaborators in India, Bangladesh and the Philippines.

The Bt Brinjal project in the Philippines

In 2004, the ABSPII Southeast Asia Center initiated the project to develop FSB-resistant brinjal in the Philippines. The Bt event conferring resistance to the FSB was donated by Mahyco to the University of the Philippines Los Baños (UPLB) for use in developing local FSB-resistant brinjal varieties for the Philippines. The ABSP II Southeast Asia Center executes the project through the UPLB Foundation, Inc. with the Institute of Plant Breeding of UPLB as lead implementing unit.

Since then, the Philippines has advanced the project to the stage of having completed the first field trial of promising brinjal lines with resistance to FSB. The next phase of the project is the multi-location trials. The activities of the different stages are summarized as follows:

Product Development Stage	Activity/Trial	Expected Year of Implementation	Regulatory Body
Research and Development	**Contained Trial** • Backcrossing • Selfing	2004 - 2007	National Committee on Biosafety of the Philippines (NCBP)
	Confined Trial • Line Selection • Field bioefficacy • Generation Advancement • Studies on arthropods and non-target organisms • Stability of the event (including gene strip tests/confirmatory study)	late 2007 - 2008	
Pre-commercialization and commercialization	Multi-location trials		Department of Agriculture-Administrative Order 8 (DA-AO8)

The multi-location trials which are the penultimate phase prior to possible commercialization of the product, are yet to be done in the Philippines. The experiences and knowledge gained by India with the multi-location trials of Bt brinjal accomplished in 2007, and the current multi-location trials in Bangladesh, could be helpful to the Philippines as the latter undergoes the same stages. In similar manner, the multi-location trials in the Philippines could provide India and Bangladesh with the opportunity to validate and compare the information they obtained through comparing their study results with that of the Bt brinjal's in the Philippines. Thus, collaborating countries gain more insights through their inter-country partnership.

Philippines-India Partnership

As a strategy in solving a major brinjal production constraint, the private-public partnership translates into mutual benefit sharing between the country-partner collaborators. Both India and the Philippines gain from this kind of partnership. For one, the very valuable package of regulatory information provided by Mahyco could significantly reduce the cost of complying with regulatory requirements in the Philippines and also help facilitate the acceptance of the technology by key stakeholders such as farmers, researchers and consumers in the country. Likewise, the information generated by Mahyco with the Bt brinjal becomes a point of reference for the Philippines, allowing a science-based evaluation of the merit of the Bt brinjal project by concerned regulatory bodies. As the first biotech food crop to be released in the Philippines, any issues and concerns on the risk assessment of the product can be adequately addressed with the results of the comprehensive studies that Mahyco had undertaken.

On the other hand, India can also benefit from the Philippine data gathered for the regulatory file development of the Bt brinjal. The results of the studies obtained in India can be substantiated by the results of studies done in the Philippines thereby validating the value of the technology. In particular, confirmation of the bioefficacy of the event under local condition represents an independent, unbiased, and additional validation of the broad geographic effectiveness and utility of the technology. The basic studies done locally can guide Indian counterparts to look into similar studies which can support existing body of information.

The progress in India with regard to the commercialization of the Bt brinjal is much anticipated by other country-partner collaborators where the same Bt event is being utilized for possible eventual commercial deployment. This is also an acknowledgement of the Indian government's leadership and focus on science and technology for national development goals. Furthermore, the potential of private-public and South-South partnerships in addressing similar problem in the future can be illustrated by the experiences derived from implementing the Bt brinjal project.

Project Components	Gains	
	Philippines	India
Product Development	• Benchmark information, relevant documents as references to research proposal submitted to regulatory bodies • Promising FSB-resistant selections	• Information from local studies/trials to validate results of previous studies • Confirmation of the efficacy of the event
Regulatory file development	• Local data to support proposal for field trials and commercialization	• Collection of regional data to support existing regulatory dossiers
Information, extension and communication	• Introduction and wide acceptance of the technology to the public and key stakeholders	• Support the effort to commercialize the product through positive feedback from print media of country-partner collaborators
Capacity Building	• Training on the Bt technology • Network of contacts and potential collaborators	• Research visits and discussion meetings with Philippine scientists. • Network of contacts and potential collaborators

There are potential benefits to be gained from regional harmonization of regulatory procedures for neighboring countries which have common regulatory requirements. The lack of simplified, responsible and harmonized regulations for biotech crops is a barrier that denies developing countries access to the significant benefits that biotech crops offer. True enough, the experiences of India with the Bt brinjal is applicable to the on-going trials of Bangladesh and the Philippines. Not only does India's insights help facilitate regional harmonization of biotech crops in Asia, it can also serve the common regulatory needs in Bangladesh and the Philippines.

Aside from regulatory harmonization, other insights in terms of farming benefits may also be gained from this kind of partnership. India, Bangladesh and the Philippines recognize the brinjal as an important crop in their agriculture industry. All three countries have the same problems in terms of pest and pesticide use, as well as yield crop loss due to these factors. With similar experiences in the field, the farming benefits of the Bt brinjal in all three countries are more or less the same.

Socioeconomic and Environmental Benefits in the Philippines

Studies (Francisco 2007a; 2007b) characterizing the potential impacts of the adoption of Bt brinjal in the Philippines show significant economic and environmental benefits of the technology. Farmer adoption of Bt brinjal could provide additional income of PhP49,802/ha. The significant increase in income is due to increased marketable yield by as

much as 40% and savings from insecticide use and labor costs. The technology could provide an estimated PhP1.864 million economic benefits to brinjal producers and consumers.

On average, brinjal farmers apply 65.6 liters of pesticides per hectare, with total active ingredient (a.i) of around 12 kg. a.i/ha. The use of Bt brinjal can significantly reduce pesticide use by as much as 48% as the technology replaces broad spectrum of pesticides. In effect, the use of the technology can reduce environmental footprint by about 20%

Table 1: Reduction in environmental footprint from changes in pesticide use associated with Bt

Particulars	Without Bt brinjal	With Bt brinjal	Difference
Pesticide use (kg a.i./ha)	11.98	6.22	5.76
Field EIQ	245.59	197.75	47.84
% change in pesticide use			49.08
% change in EIQ footprint			19.48

Reduction in the use of pesticides also have implications to farmers' health. As indicated in other studies elsewhere, health costs savings is realized with the use of Bt technology.

REFERENCES:

ABSP II. 2005 - 2008 Annual Technical Reports

Francisco, S.R. 2007a. "Ex-ante Economic Impact Assessment of Bt brinjal Crop Production in the Philippines", *Philippine Journal of Crop Science*, 32(2): 3-14

Francisco, S.R. 2007b. *Environmental Impacts of Bt brinjal in the Philippines. Final Report submitted to the International Service for the Acquisition of Agri-biotech Applications (ISAAA) and Agricultural Biotechnology Support Project II (ABSPII)*, October 2007

2008. *Development and Commercialization of Fruit and Shoot Borer-Resistant (FSB-R) Brinjal in the Philippines.* PowerPoint presentation of the Information Resource Kit in the Philippines. Unpublished.

Introducing Bt Brinjal in Bangladesh

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Brinjal, *Solanum melongena* L. is one of the most common and widely consumed vegetable in Bangladesh. Brinjal is cultivated in the country mainly on small family farms and forms a source of cash income. The estimated area under brinjal cultivation in Bangladesh is 57,745 hectares with total production of 339,795 Mt (BBS, 2008).

Brinjal growers world over have been combating pest infestation in their crops from time immemorial. One insect pest that has been extensively damaging this staple vegetable crop is the brinjal fruit and shoot borer (*Leucinodes orbonalis*).

The young larvae of this pest bore into petioles and midribs of large leaves and tender shoots causing wilting of the shoot tips and later by boring into flower buds and fruits they damage them causing considerable reduction in its yield and loss of market value. The pest poses a serious problem because of its high reproductive potential, rapid turnover of generations and intensive cultivation of brinjal both in wet and dry seasons of the year. Around 25 to 160 sprays in a crop season are undertaken for the effective control of brinjal shoot and fruit borer. Most brinjal growers have opined that insecticidal spray is not fully effective which might be due to development of resistance.

The Agricultural Biotechnology Support Project II (ABSPII) funded by the USAID works towards empowering resource-poor farmers through the safe and effective development and deployment of bio-engineered crops with the objective of boosting food security, economic growth, nutrition and environmental quality. The Bangladesh government inked a memorandum of understanding with ABSPII for the development of lepidopteran specific *Cry1Ac* gene transformed Bt brinjal that would provide an effective built-in resistance towards brinjal shoot and fruit borer..

Introgression of Bt gene to local cultivars

Under the public private partnership initiative of the ABSPII, the Bt gene (*Cry1Ac*) was donated by the Maharashtra Hybrid Seed Company (Mahyco), India in year 2005, through which, the scientists at the Bangladesh Agricultural Research Institute (BARI) developed the transgenic Bt brinjalBt brinjal by introducing the Bt gene (*Cry1Ac*) into nine popular Bangladeshi cultivars of Brinjal.

Chronology of Bt Brinjal Development Under the Regulatory System in Bangladesh

- 2005-Backcrossing program initiated (BC1) at Mahyco.
- 2006-BC2
- 2007-BC3, BC3 (F2)
- 2008 -BC3 (F3), BC4, MLT with BC3 F2

Variety /lines included in the Bt brinjal program

Variety	Characters
 **Uttara**	Prostrate growth habit, cluster bearer, medium long cylindrical shaped, uniform shiny light purple color, early bearer, heat tolerant, popular through out the country.
 **Kazla**	Intermediate growth habit, cluster bearer, medium long cylindrical shaped, uniform purplish black color, popular through out the country
 **Nayantara**	Intermediate growth habit, solitary bearer, round shaped, uniform purplish black color, early bearer, getting popularity

Variety /lines included in the Bt brinjal program

Variety	Characters
 **ISD 006**	Intermediate growth habit, solitary bearer, oblong shaped, uniform light green color, late bearer, popular in Pabna (middle) region
 **Singhnath (B 009)**	Upright growth habit, cluster bearer, fruits curved long cylindrical with tapered end, uniform purplish black color, popular through out the country.
 **Khatkhatia (BL 117)**	Upright growth habit, cluster bearer, fruits curved long cylindrical with tapered end, greenish purple fruits, popular in Rangpur (north) region
 **Dohazari (BL 072)**	Intermediate growth habit, cluster bearer, oblong shaped, shiny dark green with white stripe mottled with pinkish shade fruits, late bearer, popular in Chittagong (south-east) region
 **Islampuri**	Intermediate growth habit, solitary bearer, round shaped fruits with slightly depressed end, uniform shiny dark purple fruits, late bearer, popular in greater Mymensingh (north-east) region
 **Chaga**	Intermediate growth habit, solitary bearer, elliptical shaped fruits, shiny deep green with light green strip fruit color, popular in Jessore (south-west) region

Development of transgenic crops is a highly regulated process and in consonance with the regulatory requirement of the Bangladesh government, field trials of Bt brinjal were conducted at three different BARI Research Stations in the summer of 2008. Three Bt brinjal varieties were subjected to trials at Joydebpur and two Bt brinjal varieties at both Jessore and Hathazari . The results of the MLTs of Joydebpur, Jessore, and Hathazari on marketable yield of Bt brinjal have been shown in Table 2.

Table 2: Yield of Bt and Non Bt brinjal varieties at three locations during summer 2008

Location	Variety	Marketable Yield/Plant (Kg)			Marketable Yield/ha (tonnes)		
		Bt	Non-Bt	Yield Increased	Bt	Non-Bt	Yield Increased
Gazipur	Nayantara	0.44	0.11	X 4.0	5.94	1.32	X 4.5
	Singhnath	0.91	0.45	X 2.0	12.29	6.09	X 2.0
	Uttara	1.19	0.45	X 2.6	16.16	6.06	X 2.7
Jessore	Chaga	1.18	0.28	X 4.2	3.90	0.74	X 5.3
	Uttara	3.80	1.70	X 2.2	60.30	29.60	X 2.0
Hathazari	Dohazari	0.66	0.46	X 1.4	9.30	6.52	X 1.4
	ISD 006	0.55	0.38	X 1.4	7.70	5.40	X 1.4

The Bt version of brinjal varieties developed have shown resemblance to the non-Bt brinjal varieties, implying proper selection of brinjal populations through breeding techniques. In terms of marketable yield per plant and per hectare, Bt brinjal varieties showed marked variation in all locations over non-Bt counterparts.

In all the locations Bt varieties had maximum marketable yield per plant (1.44 - 4.0 times higher) when compared to their non Bt counterparts, the details of which are exhibited in Table 2. The actual yield potential of the Bt brinjal varieties was not expressed because the trials were held during the summer rainy season, which was the optimum time for assessing the impact of brinjal shoot and fruit borer (FSB).

Incidence of FSB and other pests and predators in Bt and non-Bt brinjal varieties from three locations was also documented from the same trial, which shows that infestation was much less in the Bt brinjal varieties when compared to their non-Bt counterparts. and the data is presented in Table 3. The incidence of non-target pests such as leaf folder, Jassids, whiteflies, lady bird beetle and spiders were more or less similar in Bt and non-Bt brinjal varieties. The observed intensity of FSB over three locations with 6 varieties indicated that the Bt version of brinjal would be able to provide adequate protection from the attack of BSFB. For sucking pest, 2-3 cover sprays of insecticides may be required.

Table 3: Incidence of BSFB in Bt and Non Bt brinjal varieties at three locations during summer 2008

Location	Variety	% Shoot Infestation		% Fruitoot Infestation	
		Bt	Non-Bt	Bt	Non-Bt
Gazipur	Nayantara	1.68	17.03	17.65	31.58
	Singhnath	14.25	10.79	13.40	20.72
	Uttara	1.34	11.77	11.65	79.80
Jessore	Chaga	0.27	4.19	6.43	51.54
	Uttara	0.30	8.38	6.94	53.13
Hathazari	Dohazari	0.05	1.3	7.63	34.90
	ISD 006	0.12	2.31	8.38	39.62

Resistance Management Strategies for Bt Brinjal

In order to achieve the agronomic benefits provided by Bt brinjal, it is important that brinjal with Bt gene be deployed and managed to sustain the technology. This can only be achieved by implementation of integrated pest management techniques and the use of strategies to delay the development of insect resistance to Cry1Ac protein. To address the possible strategies that could be employed to reduce the likelihood of target insects developing resistance to the Cry1Ac protein in Bangladesh, BARI scientists have collaborated closely with leading pest and resistance management to the researchers of the partner organizations. In collaboration with the experts, laboratory and field studies have been conducted to evaluate strategies for managing caterpillar resistance to the Cry1Ac protein. Results from these experiments, combined with an understanding of brinjal production and agronomic practices, provide the basis for a sound, practical, resistance management program.