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Potential Benefits of Bt Brinjal in India — An Economic Assessment[§]

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Abstract

The potential economic benefits of Bt brinjal hybrids in terms of yield gain, reduction in insecticide-use, and increase in net returns per hectare have been reported in this study. Results have shown that adoption of Bt brinjal hybrids would provide yield gain of 37 per cent and reduction in total insecticide-use of about 42 per cent over non-Bt hybrids. Other benefits like increase in additional brinjal production (30 thousand tonnes), savings from insecticides (₹ 47 crore) against Fruit and Shoot Borer (FSB), increase in net returns (₹ 11029/ha), and reduction in price of brinjal output (3%), etc. would be at 15 per cent adoption level. With increased adoption level of 60 per cent of Bt brinjal hybrids would provide, additional production of 119 thousand tonnes, savings from insecticides against FSB Rs 187 crore, increase in net returns ₹ 44117/ha and likely reduction in brinjal price by 15 per cent. Simulation of gains adopting Bt brinjal hybrids has shown that country may gain aggregate direct economic benefits between ₹ 577 crore and ₹ 2387 crore annually at 15 per cent and 60 per cent adoption levels of bt brinjal hybrids, respectively. The major gains will accrue to consumers (66% of total) and rest would go to the farmers. In brief, Bt brinjal offers a large scope to increase income of farmers, reduce its cost to consumers, improve food safety and reduce health hazards and environmental pollution. The results of study may be helpful in policy decision on Bt brinjal adoption in the context of smallholders agriculture.

Key words: GM food crop**,** Bt brinjal hybrid, Fruit and shoot borer, Economic benefits

JEL Classification: Q11, Q15, Q16

Introduction

Brinjal (*Solanum melongena* Linn) is the fourth most important vegetable after potato, onion and tomato in India (Figure 1). Three crops of brinjal are planted in India; first during the *kharif* season (June-September), second during the *rabi* season (November-February) and third in the month of March. In India, brinjal is primarily grown by small and marginal farmers for whom it is an important source of income. But, the production of brinjal faces a number of problems which cause enormous yield losses. Among the insect-pests, the most devastating is the fruit and shoot borer (FSB), which not only causes a significant yield loss (60-70%), but deteriorates the product quality also, making the produce less remunerative. For managing FSB, farmers rely mainly on the application of chemical pesticides. The consecutive, excessive and indiscriminate use of chemical pesticides is causing multiple side-effects that include exposure of farm labourers and consumers to pesticide residues, increased cost of cultivation, environmental pollution, destruction of natural enemies of pests, resurgence of pest population, etc. The other methods to control FSB, like integrated pest management, mechanical control, etc. are not much popular among farmers due to lack of collective action, high labour requirements and difficulties involved in their

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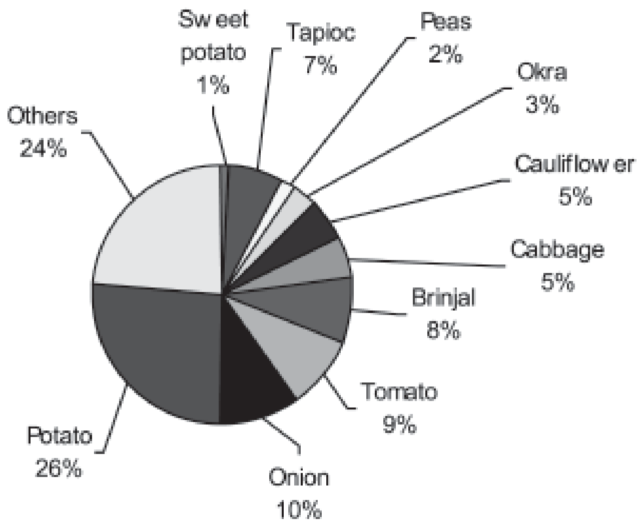

Figure 1. Production share of major vegetables in India: TE 2009

application. Further, transgenic/genetically modified technology has emerged as an alternative to chemicals in controlling insect-pests, reducing herbicides, managing related problems, and providing many other benefits. Simultaneously, application of genetically modified (GM) technology has raised some apprehensions like safety of food, affordability of technology, loss of biodiversity, protection of environment, etc. But, should the GM technologies that are capable to overcome daunting challenges (i.e. food, nutrition and environmental security, etc.) faced by the planet be sacrificed in the midst of fear and ignorance! (Qaim, 2010).

Even though the experience with cultivation of Bt (*Bacillus thuringiensis*) cotton in India has provided a strong evidence to convince various stakeholders about the benefits of GM or biotech crops, concerns have been expressed about the ability of small farmers to participate in biotech crops cultivation, which involves issues like large capital, new skills, affordability, etc. Nevertheless, the first GM food crop viz. Bt brinjal, has been developed in India and it can be readily taken for field cultivation. Further, several studies have demonstrated the potential of insect-resistant GM crops in increasing crop productivity and reducing insecticide-use on plants in the developing countries (Krishna and Qaim, 2008; Hareau *et al.*, 2006; Huang *et al.*, 2005; Qaim and Traxler, 2005). Globally, many biotech crops, namely cotton, maize, soybean, and canola, are being grown on a large scale and both public and private sectors are investing heavily for harnessing the potential of this technology. But, whether the development of biotech technologies would be a profitable venture for crops grown in smaller areas is still not clear. Considering some such unanswered queries and implications of biotech food crop, the government has imposed a moratorium on the release of Bt brinjal for cultivation. This paper aims to contribute to the debate on potential benefits of Bt brinjal in terms of yield gain, reduction in insecticide-use, and monetary benefits to producers, consumers and society in the context of smallholder agriculture.

Data and Methodology

Brinjal adapts well to all the agro-climatic conditions and is grown in almost all parts of India. To capture agro-climatic variability, the country was divided into 4 regions, viz. eastern, western, northern and southern, based on geographic locations. Data used in this study on production and prices of brinjal at all-India and for selected regions (for 2008) were taken from the *Indian Horticulture Database* (NHB, 2009). Data on farmers growing brinjal in the major states of India were taken from a wide field survey conducted recently*. The sample of brinjal growing farmers was selected by following multi-stage stratified random sampling procedure (*see* Kumar and Prasanna, 2011, for details). The potential economic benefits of Bt brinjal and its distribution between producers and consumers have been estimated using the economic surplus method, it being the most common method to evaluate the impact of commodity-related technological progress in agriculture (Alston *et al.*, 1995; Norton and Davis, 1981). The economic gains of Bt brinjal have been simulated under 3 scenarios considering its adoption level at 15 per cent, 30 per cent and 60 per cent. A lower adoption level has been assumed for the eastern region of India (particularly in West Bengal) due to use of a higher percentage of open-pollinated varieties of seeds (95%), own-saved seeds (84%), presence of a soil organism not suitable for hybrid cultivation, etc. The lower adoption base has also been assumed for the northern region. Contrary to the eastern region, application of a higher share of hybrid quality seeds (84-92%) in Gujarat and Karnataka, provided the base

* Field survey was conducted during August to October 2009 under the research project 'Ex-ante study on socio-economic benefits of Bt brinjal', undertaken by NCAP, New Delhi.

for assuming a higher adoption rate in the western and southern regions.

Production Profile of Brinjal

The brinjal has its origin in India and is being cultivated for over 4000 years in the country. More than 2000 varieties of brinjal are grown in the country. Amongst different states, the top producer of brinjal is West Bengal (28%), followed by Orissa (21%), Bihar (12%) and Gujarat (10%), as per the data of average triennium ending (TE) 2009. On the yield front, both Bihar and Karnataka produced about 21 t/ha each, while West Bengal, Gujarat, Maharashtra, and Andhra Pradesh were at par with country's average yield of 17t/ha.

A significant progress has been made in the production of brinjal in India during the past two decades (Figure 2). Between 1991 and 2009, area under brinjal cultivation increased by 52.6 per cent (from 3.8 lakh ha to 5.8 lakh ha), production increased by 94 per cent (from 50.6 lakh tonnes to 98.1 lakh tonnes), and yield rose by 26.8 per cent (from 13.4 t/ha to 17.0 t/ha). These figures show that increase in brinjal production has largely been driven by increase in its area, though yield-increase also contributed to it. Given the serious constraint on area expansion, productivity increase in brinjal will be the main source of output growth in future.

The Brinjal Farmers

The brinjal farmers in India are resource-poor and mainly belong to small and marginal farm- categories. According to one estimate, about 1.4 million small and marginal farmers in India grow brinjal crop, which provides a regular and steady income to them (Choudhary and Gaur, 2009). Our farm survey in major brinjal-producing states has also shown similar results. It has revealed that between 78 and 95 per cent of the sample farmers belonged to smallholders category (below 2 ha) in the states of Gujarat, Uttar Pradesh & Bihar and West Bengal (Table 1). The share of smallholding farmers in Karnataka was lower but still significant (50%). Therefore, the potential clients for Bt brinjal cultivation or for that matter of any other new technology of brinjal cultivation, are small and marginal farmers. The direct monetary benefit of Bt brinjal hybrids would accrue to this category of farmers.

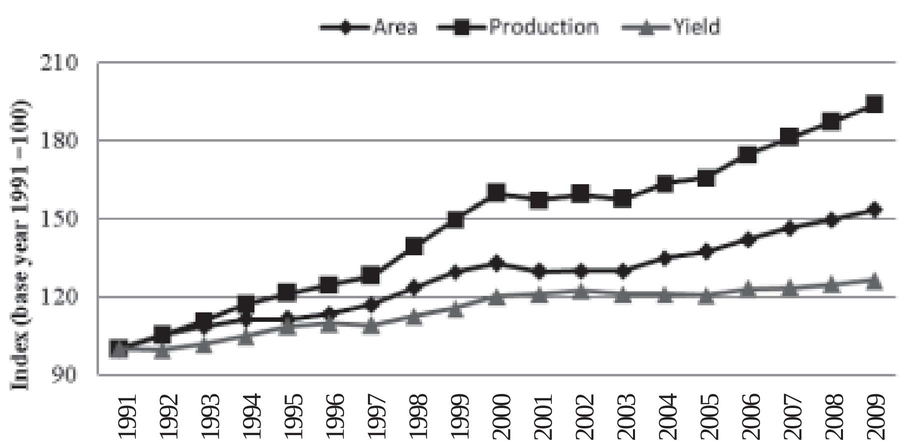

Figure 2. Progress in area, production and yield of brinjal in India: 1991-2009

Table 1. Distribution of brinjal farmers by landholding size across selected states of India

(in per cent)

Farmers by landholding size	West Bengal	Gujarat	Eastern Uttar Pradesh & Bihar	Karnataka
Marginal farmers (< 1 ha)	75.6	46.4	51.9	31.4
Small farmers (1-2 ha)	19.8	31.1	27.6	18.3
Other farmers (> 2 ha)	4.6	22.5	20.5	50.2
Average landholding size (ha)	0.79	1.43	1.44	2.38

Source: Kumar and Prasanna (2011)

Development of Bt Brinjal

The Bt-brinjal is the first GM food crop in India. It has been developed by the Maharashtra Hybrid Seed Company Ltd. (Mahyco), a leading Indian seed company, by inserting a gene *cry1Ac* from a soil bacterium called *Bacillus thuringiensis* through the *Agrobacterium tumefaciers* mediated method. Bt brinjal contains three genes, namely:

(i) The *cry1Ac* gene, which encodes an insecticidal protein *Cry1Ac*, is derived from a common soil bacterium *Bacillus thuringiensis* (Bt) subsp. *kurstaki* to produce the 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-II, and

(iii) The *aad* gene for another marker O-aminoglycoside adenyl transferase.

The expression of the *cry1Ac* genes provides an effective built-in control in brinjal crop against FSB and thus reduces pests-linked damages and protects the environment from adverse effects of pesticides. This is also expected to bring down the cultivation cost of brinjal, as the cost of chemical pesticides to brinjal cultivation is substantial. The *cry1AC* protein produced in Bt brinjal is similar in structure and function to that found in nature and in commercial B.t.k. microbial formulations. *Bacillus thuringiensis* and *B. t. k.* microbial formulations have been found to be highly specific to target insect pests, and do not have deleterious effects on non-target organisms such as beneficial insects, birds, fish, and mammals including human beings (GoI, 2009).

As Bt brinjal plants have an inbuilt mechanism of plant protection against targeted pests, the protein produced by the plants is neither washed away nor destroyed by sunlight, unlike the externally-applied pesticides. The plant is thus protected from the FSB round the clock and throughout its life.

Socio-economic Impact

The Bt brinjal hybrid is expected to provide multiple benefits to its cultivators. One, higher yield due to reduction in crop damage from FSB infestation; two, reduction in cost due to savings in insecticides-use to control FSB and; three better quality of produce which will have better market acceptability and will provide a premium price. On the other hand, the consumers will also be benefitted on several counts. Firstly, they will have access to a better quality produce which will be free from FSB-infestation and residues of chemicals; secondly, they will get brinjal at a lower rate due to reduction in output price and; thirdly, they will have more access to brinjal due to higher volume of its production.

(i) Yield Gain and Reduction in Application of Insecticide

The performance of Bt hybrids over non-Bt and popular hybrids of brinjal was examined in terms of yield gain and reduction in insecticide-use (Table 2) using data from large-scale field trials conducted by the Indian Institute of Vegetable Research (IIVR), a premier research institute under the Indian Council of Agricultural Research. These trials were conducted at 8 locations for 7 hybrid varieties of brinjal containing Bt gene, non-Bt hybrids and most popular hybrids during 2007-08 and 2008-09 to assess their marketable fruit yields. The data on reduction in insecticide-use were taken from the trials conducted by the All India Vegetable Improvement Project (AICVIP) during 2004-05 and 2005-06. The analysis revealed that use of Bt technology had resulted in a significant reduction in insecticide-use. Overall, the quantities of insecticides used against FSB were reduced by 77.2 per cent, which amounted to 41.8 per cent reduction in the total insecticide-use in brinjal (Table 2).

Table 2. Reduction in insecticide use and increase in fruit yield due to Bt brinjal hybrids

Year	Reduction in insecticide use* (%)		Increase in marketable fruit yield (%) over	
	Against FSB	Against all insect-pests	Hybrids used to develop Bt	Popular hybrids
2007-08	80.0	40.4	32.1	51.6
2008-09	74.5	43.2	45.2	58.9
Average	77.2	41.8	37.3	54.9

Note: *relates to the years 2004-05 and 2005-06
Source: IIVR (2009), and AICVIP/ ICAR (2007)

Table 3. Potential economic benefits of Bt brinjal cultivation to farmers and consumers under different adoption scenarios at all-India level

Particulars	Scenarios: Adoption level		
	I: Low (up to 15%)	II: Medium (up to 30%)	III: High (up to 60%)
Benefits to farmers			
(i) Increase in production ('000 tonnes)	29.70	59.40	118.80
(ii) Saving from insecticides for FSB (in crore ₹)	46.80	93.60	187.20
(iii) Increase in net returns (in crore ₹)	623.15	1246.30	2492.60
(iv) Increase in net returns (₹ /ha)	11029	22058	44117
Benefits to consumers			
(i) Likely reduction in brinjal price (%)	3.00	7.00	15.00

Source: Kumar *et al*. (2010)

Simultaneously, field trials data also showed yield of Bt brinjal hybrids was consistently higher than that of non-Bt hybrids. The yield gain in Bt hybrids was 37.3 per cent over non-Bt hybrids (the same as used for incorporating Bt gene) and 54.9 per cent over popular hybrids. This vast difference in yield indicated that use of Bt gene in brinjal was more effective than use of chemicals in controlling FSB infestation. And consequently, the yield loss was much lower in Bt brinjal hybrids. Overall, the incidence of shoot damage in Bt hybrids was very low, 0.24 per cent as compared to 4.64 per cent in check and 4.86 per cent in non-Bt hybrids.

(ii) Benefits to Brinjal Farmers

Farmers were benefited at multiple levels; they could save on quantity of insecticide used (Table 3), which directly affected savings in cost on insecticides and on labour in spraying of insecticides. A considerable increase observed in yield was due to low damage from FSB, which led to higher production and increase in income per unit area. Corresponding to the assumed adoption levels of Bt hybrids, brinjal output to the tune of 30 thousand tonnes to 119 thousand tonnes can be added to total production from the existing area under brinjal (Table 4). The Bt technology would also generate large savings (₹ 47 crore to ₹ 187 crore) due to reduction in insecticide-use to control FSB, and in turn, large increase in net returns. The annual additional net returns would be ₹ 11029/ha at 15 per cent adoption level, and will reach ₹ 44117/ha with adoption level of 60 per cent. Regarding labour saving, our computations did not include labour saving due to reduction in the number of pesticide sprays as experimental data did not capture this. However, our field survey revealed that 41.8 per cent reduction in pesticide-use due to Bt variety could provide a saving of 4-8 per cent in labour used for production of brinjal in major states.

Reduction in direct exposure to insecticides would lead to lesser health problems. Undoubtedly, it would offer invaluable environmental and health benefits to farmers, as reported by some studies (Krishna and Qaim, 2007; 2008).

As noted earlier, there are many issues to be resolved before adopting Bt-brinjal for field cultivation. This study has provided estimates of its potential monetary benefits which would be helpful in policy debates and decisions-making. The data used in simulating the economic gains are given in Table 4.

(iii) Benefits to Consumers

The study has revealed that adoption of Bt hybrids would benefit consumers also in terms of reduction in price of brinjal to the tune of 3 per cent to 15 per cent (Table 3). Also, additional production of brinjal (30-119 thousand tonnes) may lead to increase in its consumption level and would improve the food and nutritional security of resource-poor consumers as well as would provide better environmental security to the country.

The potential economic gains to farmers and consumers due to adoption of Bt brinjal have also been estimated in terms of the economic surpluses (both consumer and producer surpluses). The estimation has shown that adoption of Bt brinjal could raise consumer surplus by ₹ 381 crore and producer surplus by ₹ 196

Table 4. Summary data used for simulation of economic gains from Bt-brinjal hybrids

Particulars	Region/ all-India				
	Eastern	Western	Northern	Southern	All-India
1. Production (thousand tonnes)	7036	1869	482	990	10377
2. Price of brinjal without Bt (₹/kg)	7	10	7	10	8
3. Maximum yield gain (%)	33	33	33	33	33
4. Reduction in cost (%)	17	17	17	17	17
5. Price elasticity of demand	-0.515	-0.515	-0.515	-0.515	-0.515
6. Price elasticity of supply	1.0	1.0	1.0	1.0	1.0
7. Adoption rate (%)					
Scenario I	10	25	10	25	15
Scenario II	25	50	25	50	30
Scenario III	50	80	50	80	60

Source: Production and price data have been taken from NHB (2009); yield gain and reduction in cost have been taken from IIVR (2009) and AICVIP/ ICAR (2007); demand elasticity has been taken from Kumar (2010); and supply elasticity from Krishna and Qaim (2008); and adoption rates are authors' own assumptions.

Table 5. Simulated gains in annual economic surplus from Bt brinjal cultivation under different scenarios at all-India level

Scenarios	Total economic surplus (in crore ₹)	Distribution of economic surplus (in crore ₹)	
		Consumers	Producers
I : 15% adoption level	577	381	196
II : 30% adoption level	1167	770	397
III : 60% adoption level	2387	1576	811

Source: Kumar *et al.* (2010)

crore annually with adoption rate of 15 per cent (Table 5). When the coverage of Bt brinjal would extend to 60 per cent of the existing area under brinjal, consumer surplus would increase by ₹ 1576 crore and producer surplus would increase by ₹ 811 crore. The gains in economic surplus have been distributed between consumer and producer in the ratio of 66: 34.

In absolute terms, the likely gains to total economy have been estimated between ₹ 577 crore and ₹ 2387 crore annually, corresponding to different levels of adoption. It is an enormous benefit in absolute terms for a vegetable with an aggregate area-coverage much smaller than that of major food or fibre crops. Not surprisingly, the largest share in the overall gain may accrue in the eastern region, where not only brinjal area is larger but farm level productivity gains and adoption rates are also assumed to be higher after technological refinement and strong institutional mechanism. Also, a balanced approach is required, keeping in view and learning from the evolution of agriculture which sustains human life on earth, the present day knowledge, prevailing crop production practices and the need of food in future (Anonymous, 2011)

Conclusions and Policy Implications

Most of the vegetables available in the market are out of the reach of a common man due to their high prices, particularly in the recent period. The per capita availability of vegetables in the country is 190 grams per day as against the normative requirement of 280 grams per day. The vegetable deficit underscores the need for substantial increase in vegetable production and affordability to consumers. Further, the major challenge is to raise production from the limited arable land, which necessitates increase in yield as the principal source of output growth. The study has clearly shown that adoption of Bt technology can increase the yield due to reduction in insect-pest related yield losses. It can also reduce the cost of production of brinjal due to reduction in cost of insecticides (on account of lower use) and cost of labour (due to less number of applications). Reduction in insecticide-use could be considered as a comprehensive impact from environmental and health risk points of view.

The study has revealed that Bt brinjal has enormous potential to benefit both consumers and producers. Field cultivation of Bt brinjal would add between 30 thousand tonnes and 119 thousand tonnes to total production from the existing area under it. A considerable increase in net returns from Bt brinjal hybrids is also expected. The consumers would gain by way of reduction in output prices, availability of better quality of brinjal and increased consumption of brinjal. The absolute gain in economic surplus from Bt brinjal hybrids could be of ₹ 577 crore annually at the country level under scenario I (assuming adoption rate of 15%), of ₹ 1167 crore under scenario II (adoption rate of 30%), and of ₹ 2387 crore under scenario III (adoption rate of 60%). About 66 per cent of the overall potential gains would accrue to consumers, who would benefit from a technology-induced decrease in brinjal sale price. Since brinjal in India is an important vegetable across the low-income households, the price decrease in brinjal is pro-poor. A positive nutritional effect is also expected from increased vegetable consumption. On the other hand, brinjal farmers would benefit from Bt technology as increase in productivity will be larger than drop in market price.

In terms of regional distribution effects, the major share of welfare gains would accrue in the eastern states of India (West Bengal, Orissa, and Bihar), where most of the brinjal is produced and insect-pest problems are severe. To realize the welfare potentials fully, these states will need particular attention in terms of technology dissemination, product development and delivery. This needs strengthening of local seed market infrastructure. Development of Bt OPV will improve access of resource-poor farmers to technology, who might not adopt more expensive Bt hybrids due to income constraints. This will help in increasing farm income, reducing insecticide-use and contributing to ecological security. An effective policy support is also required to spread Bt technology and harness its potential.

To sum up, Bt brinjal offers a large scope to increase income of farmers, increase its supply, reduce its cost to consumers, improve food safety and reduce health hazards and environment pollution. Therefore, appropriate and effective regulatory and institutional mechanisms need to be put in place to harness the benefits and to safeguard against any threat of GM technology to environment, health, and biodiversity.

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