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Socio-Economic Impact of Bt Cotton — A Case Study of Karnataka

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Abstract

The performance Bt technology and its impact on farming community have been assessed in northern Karnataka based mainly on primary data processed using production functions, decomposition analysis and logit model. On an average, per farm area under Bt cotton was 2.21 ha, accounting for 66 per cent of the total landholding. With a yield of 24 q/ha, Bt cotton has registered 31 per cent higher yield and 151 per cent higher net return over non-Bt, the net additional benefit being ₹ 18429/ha. The non-Bt cotton farmers use chemical fertilizers, organic manures and bullock labour excessively which result in a lower net returns. Technology has been found the major contributor to the total productivity difference between Bt and non-Bt cottons. Seed cost, yield of Bt cotton and cost of plant protection have been found to greatly influence the probability of adoption of Bt cotton. Non-availability of quality seeds and in required quantity have been identified as the most important factors constraining Bt technology adoption. The impact of Bt cotton, as perceived by the farmers, has been in terms of enhanced yield; reduced pest and disease incidence; increased income, employment, education and standard of living; and reduced health risk. To foster adoption, availability of quality and quantity of Bt cotton seed to farmers needs greater attention of development agencies, while researchers' attention is called for incorporating resistance/ tolerance to *Spodoptera* and pink bollworms.

Key words: Bt cotton, Bt technology, Bt crop, Karnataka

JEL Classification: Q16, Q12

Introduction

As a result of the consistent and substantial economic, environmental and welfare benefits offered by biotech crops, millions of small and resource-poor farmers around the world continued to plant more area with biotech crops in 2008, the thirteenth year of their commercialization. Progress was made on several important fronts in 2008 with significant increase in the cultivation of biotech crops; increase in the number of both countries and farmers planting biotech crops globally; substantial progress in Africa, where the challenges are big; increased adoption of stacked traits; and introduction of a new biotech crop. These are very important developments given that biotech crops can contribute to some of the major challenges being faced by global society, including food security, high prices of food, sustainability, alleviation of poverty and hunger, etc. and can help mitigate some of the challenges associated with climate change (ISAAA, 2008).

In 2008, the global acreage of biotech crops continued to grow strongly reaching 125 Mha with the number of countries planting biotech crops reaching the historical milestone of 25 countries, comprising 15 developing and 10 industrial countries. This strong growth has provided a very broad and stable foundation for the future global growth of biotech crops. The growth rate between 1996 and 2008 witnessed an unprecedented 74-fold increase, making it the fastest global status of commercialized adopted crop technology

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Table 1. Country-wise area of Bt crops (2008-09)

Rank	Country	Area (M ha)	Bt crops
1*	USA	62.5	Soybean, maize, cotton, canola, squash, papaya, alfalfa
2*	Argentina	21.0	Soybean, maize, cotton
3*	Brazil	15.8	Soybean, cotton
4*	Canada	7.6	Canola, maize, soybean
5*	India	7.6	Cotton
6*	China	3.8	Cotton
7*	Paraguay	2.7	Soybean
8*	South Africa	1.8	Maize, soybean, cotton
9*	Uruguay	0.7	Soybean, maize
10*	Bolivia	0.6	Soybean
11*	Philippines	0.4	Maize
12*	Australia	0.2	Cotton
13*	Mexico	0.1	Cotton, soybean
14*	Spain	0.1	Maize
15	Chile	< 0.1	Maize, Soybean, Canola
16-17	Colombia/ Burkina Faso	< 0.1	Cotton
18-25	Honduras/ Czech Republic/ Romania/ Portugal/ Germany/ Poland/ Slovakia/ Egypt	< 0.1	Maize

*14 biotech mega-countries growing 1,00,000 ha or more of biotech crops.
Source: ISAAA (2008)

in recent history. It is projected to cross 1.2 billion ha with over 1.6 billion accumulated ha by 2015, the year of Millennium Development Goals. The top eight countries which individually grew Bt crops in more than 1 M ha in the decreasing order of acreage (in M ha) were: USA (62.5), Argentina (21.0), Brazil (15.8), India (7.6), Canada (7.6), China (3.8), Paraguay (2.7) and South Africa (1.8) (Table 1). In 2008, the number of farmers benefiting from biotech crops globally reached 13.3 million, of which over 90 per cent or 12.3 million were small and resource-poor farmers. Of these 12.3 million small and resource-poor farmers, most were Bt-cotton farmers — 7.1 million in China (Bt cotton), 5.0 million in India (Bt cotton), and the balance of 0.2 million in the Philippines (biotech maize), South Africa (biotech cotton, maize and soybean) and the other eight developing countries.

In India, the chronology of Bt cotton started in the year 1995 when the Department of Biotechnology (DBT) of the Government of India, permitted import of 100 grams of transgenic Cocker-312 variety of cottonseed cultivated in the United States by Monsanto. This variety contained the Cry1 AC gene from the bacterium *Bacillus thuringiensis*. Since then several developments have taken place in the country (Table 2) and finally in March 2002, the Genetic Engineering Approval Committee (GEAC) under the Department of Biotechnology, Ministry of Environment, Government of India, accorded permission for the first GM crop — cotton — to a joint-venture of Mahyco–Monsanto for its three hybrids, viz., MECH-12, MECH-162 and MECH-184 for commercial cultivation and thereafter, plenty of Bt cotton hybrids from the private sector are being approved every year by GEAC (Jayaraman, 2004; Anon., 2006). Thus, Bt cotton appeared to be the first transgenic crop put into commercial cultivation in India. About 44,500 ha area was planted by 54,000 farmers with Bt-cotton in May–June 2002 (James, 2002), which has increased to 34.61 lakh ha, accounting for 37.90 per cent of the total area under cotton (James, 2006).

During 2008-09, about 5 million small farmers were benefited from planting 7.6 M ha with Bt-cotton in the country, depicting a high adoption rate of 82 per cent (Table 3). Benefits vary according to varying pest infestation levels in different years and locations.

Table 2. Timeline summary for regulatory processes leading to commercial release of Bt cotton in India

Years	Regulatory processes / Studies undertaken / Developments	Government of India oversight committees
1995-1996	Application and permit for importation of Bt cotton seed containing the *Cry1Ac* gene	DBT
1996-2000	Greenhouse breeding for integration of the *Cry1Ac* gene into Indian germplasm, seed purification, and stock increase	DBT
1996-2000	Limited field studies for potential of pollen escape, aggressiveness, and persistence	RCGM (DBT)
1998-2001	Biochemical and toxicology studies	RCGM (DBT), GEAC
1998-2000	Multilocation field trials: Agronomic and entomology performance of first-generation Bt cotton hybrids, conducted by Mahyco and state agriculture universities	RCGM (DBT), MEC
2000-2001	Soil rhizosphere evaluations and protein expression analyses from multilocation field trials	RCGM (DBT), GEAC
2001	Advanced stage multilocation field performance trials of first-generation Bt cotton hybrids, conducted by ICAR	GEAC, ICAR, DBT, MEC
2002	Submission of final biosafety, environmental safety, gene efficacy & performance documentation to GEAC; commercial release of first-generation Bt cotton hybrids by GEAC	GEAC
2002-ongoing	Continued field performance trials of second-generation Bt cotton hybrids for regulatory approval	RCGM (DBT), GEAC, ICAR, MEC

Note: DBT=Department of Biotechnology; GEAC=Genetic Engineering Approval Committee; RCGM=Review Committee for Genetic Modification (constituted by DBT); ICAR=Indian Council of Agricultural Research; MEC=Monitoring & Evaluation Committees (constituted by GEAC and RCGM).

Source: Barwale *et al. (*2004)

Table 3. Area under Bt-cotton in India: 2002-03 to 2008-09

Year	Bt-cotton area ('000 ha)	Total cotton area ('000 ha)	Per cent area occupied by Bt-cotton	No. of Bt cotton farmers ('000)
2002-03	29	8730	0.3	20
2003-04	86	7670	1.1	75
2004-05	553	7630	7.3	350
2005-06	1267	8920	14.2	1000
2006-07	3800	9158	41.5	2300
2007-08	6200	9400	66.0	3800
2008-09	7600	9300	82.0	5000

Source: ISAAA (2008)

However, on an average, conservative estimates for small farmers indicate that yield increased by 31 per cent, insecticide application decreased by 39 per cent, and profitability increased by 88 per cent, equivalent to ₹ 10,000/ha. In addition, in contrast to the farm households planting conventional cotton, Bt-cotton farm households enjoyed the emerging welfare benefits including more prenatal care and assistance with at-home births for women, plus a higher school enrolment of their children, and a higher percentage of children vaccinated (ISAAA, 2008).

The Indian government has approved 263 Bt-cotton hybrids till 2007-08. In 2007-08, the state of Maharashtra topped in terms of area (in lakh ha) under Bt cotton (28.8) (Table 4), followed by Andhra Pradesh (11.9), Gujarat (8.18), Northern Zone (Punjab, Haryana and Rajasthan) (5.92), Madhya Pradesh (5.0), Karnataka (1.45) and Tamil Nadu (0.70), according to

Table 4. Increasing adoption of Bt-cotton across different states of India

('000 ha)

State	2004-05	2005-06	2006-07	2007-08
Maharashtra	200	607	1,840	2,880
Andhra Pradesh	75	280	830	1,190
Gujarat	122	150	470	818
Northern zone*	-	60	215	592
Madhya Pradesh	80	146	310	500
Karnataka	18	30	85	145
Tamil Nadu	5	27	45	70
Others	-	-	5	5
Total	500	1,300	3,800	6,200

***Punjab, Haryana, Rajasthan**

Source: ISAAA (2008)

the International Service for the Acquisition of Agri-Biotech Applications (ISAAA, 2008). Within Karnataka, the area under Bt cotton was highest in the Haveri district (> 60,000 ha), followed by the districts of Belgaum, Raichur, Mysore, Gulbarga, Dharwad and Uttara Kannada (Table 5).

A number of studies carried out on Bt-cotton both before and after its commercialization, have indicated the following benefits: (a) higher cotton yield owing to effective control of bollworms, (b) drastic reduction in the application of chemical insecticides for bollworm control, (c) higher net returns to farmers, and (d) conservation of biological control agents and other beneficial organisms. However, the empirical estimates of these benefits based on ground level data were few and far between. Keeping in view the importance of Bt crops in the agricultural economy of the Karnataka state, the present study was formulated to assess the impact of Bt technology in northern Karnataka. The specific objectives of the study were:

Table 5. Area under Bt cotton in Karnataka: 2007-08

Sl No.	District	Area (ha)
1	Haveri	60729
2	Belgaum	14170
3	Raichur	9717
4	Mysore	8097
5	Gulbarga	8097
6	Dharwad	6073
7	Uttara Kannada	6073
8	Chitradurga	4858
9	Davangere	4858
10	Bijapur	4049
11	Bagalkot	2024
12	Bidar	2024
13	Gadag	1215
14	Shimoga	405

Source: ISAAA (2008)

- To analyse the input utilization pattern, productivity and cost-return profiles of Bt and non-Bt cotton production;
- To assess the resource-use efficiency in Bt cotton as well as non-Bt cotton production;
- To estimate the contributions of technology and inputs into the estimated productivity difference between Bt and non-Bt cottons;
- To model the farmer's decision to adopt Bt cotton technology and explore the reasons for its non-adoption; and
- To understand the dimensions of impact of Bt technology through farmers' perceptions.

Data and Methodology

For in-depth investigations, a sample of 60 farmers was chosen using the multi-stage random sampling method. In the first stage, the district with highest area under Bt cotton crop in Karnataka during 2007-08, namely, Haveri district, was purposively selected for the study. Secondly, Hirekerur and Hanagal taluks were purposively selected for the study as the cultivation of Bt cotton and non-Bt cotton, respectively, was mostly concentrated in these taluks. At the third stage, five villages from among the predominantly cotton-growing villages in each of these taluks were randomly selected. Finally, a sample of 60 farmers comprising 30 Bt farm households from Hirekerur taluk and 30 non-Bt farm households from Hanagal taluk were randomly chosen. For evaluating the specific objectives of the study, requisite primary data pertaining to the agricultural year 2007-08 were collected from the sampled farmers by personal interview method with the help of pre-tested and well-structured schedule. The data thus collected were processed using tabular analysis, multiple regression/ production function, decomposition analysis and logit model.

Production Function Analysis

To study resource productivity and allocative efficiency in Bt and non-Bt cotton production, Cobb-Douglas type of production function was fitted. The general form of the function is $y = ax_i^{bi}$ where, 'x_i' is the variable resource measure, 'y' is the output, 'a' is a constant and 'bi' estimates the extent of relationship between x_i and y and when x_i is at different magnitudes. The 'b' coefficient also represents the elasticity of production in Cobb-Douglas production function analysis. This type of function allows for either constant or increasing or decreasing returns to scale. It does not allow for total product curve embracing all the three phases simultaneously. Test was conducted to see if the sum of regression coefficients was significantly different from unity. Functions of the form of Equation (1) were fitted for Bt and non-Bt farmers separately.

$$\ln Y = \ln b_0 + b_1 \ln S + b_2 \ln F + b_3 \ln C + b_4 \ln P + b_5 \ln H + b_6 \ln B + b_7 \ln M + u_i \quad \ldots(1)$$

where,

Y = Gross returns (Rs/ha)

S = Seed costs (kg/ha)

F = Farm yard manure (tonnes/ha)

C = Chemical fertilizers (kg/ha)

P = Plant protection chemicals (Rs/ha)

H = Human labour (human days/ha)

B = Bullock labour (pair days/ha)

M = Machine time (hours/ha)

b_j = Regression coefficients (j=0,1,2…,k) (k=7), and

u_i = Error-term (i=1,2,…,n) (n=30)

Decomposition Analysis

The output decomposition model as developed by Bisaliah (1977) was used for investigating the contribution of various constituent sources to the productivity difference between the potential farm and the farmers' field. For any two production functions, the total change in the productivity could be brought out by shifts in the production parameters that defined the production function itself and by the changes in the input-use levels. Therefore, the production functions are considered as the convenient econometric models for decomposing the productivity difference. The output decomposition model used in this study was:

$$\ln Y_1 = \ln b_{01} + b_{11} \ln S_1 + b_{21} \ln F_1 + b_{31} \ln C_1 + b_{41} \ln P_1 + b_{51} \ln H_1 + b_{61} \ln B_1 + b_{71} \ln M_1 + u_i \quad \ldots(2)$$

$$\ln Y_2 = \ln b_{02} + b_{12} \ln S_2 + b_{22} \ln F_2 + b_{32} \ln C_2 + b_{42} \ln P_2 + b_{52} \ln H_2 + b_{62} \ln B_2 + b_{72} \ln M_2 + u_i \quad \ldots(3)$$

$$\ln Y_3 = \ln b_{03} + b_{13} \ln S_3 + b_{23} \ln F_3 + b_{33} \ln C_3 + b_{43} \ln P_3 + b_{53} \ln H_3 + b_{63} \ln B_3 + b_{73} \ln M_3 + u_i \quad \ldots(4)$$

where, Y, S, F, C, P, H, B, M, b_j and u_i are as denoted in Equation (1). However, Equations (2), (3) and (4) represent Bt-cotton, non-Bt cotton and pooled regression functions, respectively.

$$\ln Y_1 - \ln Y_2 = \ln (Y_1 / Y_2) = \{\ln b_{01} - \ln b_{02}\} + \{(b_{11} - b_{12}).\ln S_2 + (b_{21} - b_{22}).\ln F_2 + (b_{31} - b_{32}).\ln C_2 + (b_{41} - b_{42}).\ln P_2 + (b_{51} - b_{52}).\ln H_2 + (b_{61} - b_{62}).\ln B_2 + (b_{71} - b_{72}).\ln M_2\} + \{b_{11.}\ln(S_1/S_2) + b_{21.}\ln(F_1/F_2) + b_{31.}\ln(C_1/C_2) + b_{41.}\ln(P_1/P_2) + b_{51.}\ln(H_1/H_2) + b_{61.}\ln(B_1/B_2) + b_{71.}\ln(M_1/M_2)\} \quad \ldots(5)$$

In other words,

[Output Δ] = [Technology Δ Effect] + [Input-use Efficiency Δ Effect] + [Input usage Δ Effect]

The decomposition Equation (5) gives an approximate measure of the percentage change in output with the adoption of Bt in the production process. The first flower bracketed expression on the right hand side of Equation (5) is the measure of percentage change in output due to shift in scale parameter of the production function. The second flower bracketed expression is the difference between output elasticities each weighted by natural logarithms of the volume of that input used under non-adopter category, a measure of change in output due to shift in slope parameters (output elasticities) of the production function. The third flower bracketed expression is the sum of the natural logarithms of the ratio of each input of adopters to non-adopters, each weighted by the output elasticity of that input. This expression is a measure of change in output due to change in per ha quantities of inputs used in the production process.

Logit Model

To identify and analyse the factors that governed the farmer's decision to adopt Bt technology, the logit model analysis was carried out. The influence of various socio-economic factors on the willingness of decision makers to adopt new technologies has been investigated by a number of studies (Shakya and Flinn, 1985; Thomas *et al.*, 1990; Satyasai *et al.*, 1997; Kiresur *et al.*, 1999 and Nayak and Kiresur, 2001). In most of the studies on adoption behaviour, the dependent variable is constrained to lie between 0 and 1 and the models used are exponential functions (Kebede *et al.*, 1990). Univariate logit model and its forms have been used extensively to study the adoption behaviour of farmers. It is generally recommended to use probit model for functional forms with limited dependent variables that are continuous between 0 and 1 and logit model for discrete dependent variables. Thus, the univariate logit model, as specified below, was estimated using the maximum likelihood method.

$$\ln [\{P(Bt/X)\}/\{P(NBt/X\}] = XB + E \qquad \ldots(6)$$

$$\ln [\{P(Bt/X)\}/\{1-P(Bt/X)\}] = XB + E \qquad \ldots(7)$$

where,

P (Bt/X) = Probability of an individual farmer becoming an adopter of Bt technology, given the level of X,

P (NBt/X) = Probability of an individual farmer becoming an adopter of non-Bt technology or non-adopter Bt technology, given the level of X,

= 1-P (Bt/x)

$$[\{P(Bt/X)\}/\{P(NBt/X)\}] = \{P(Bt/X)\}/\{1-P(Bt/X)\}]$$

= The relative odds of a farmer's adoption versus non-adoption of the Bt technology,

X = Vector of explanatory variables,

B = Vector of response coefficients, and

E = Vector of random disturbances.

The specific logit model estimated to predict the logarithm of "relative odds of a farmer's adoption versus non-adoption of the Bt technology" was specified as per Equation (8):

$$\ln [P_i/(1-P_i)] = b_0 + b_1CST_i + b_2EDN_i + b_3AGE_i + b_4LHOLD_i + b_5FAMSIZE_i + b_6PPC_i + b_7SEED_i + b_8LABOUR_i + b_9YIELD_i + U_i \qquad \ldots(8)$$

where,

P_i = Probability that the i^{th} farmer is a adopter of the Bt technology,

$1-P_i$ = Probability that the i^{th} farmer is not an adopter of the Bt technology,

CST = Caste (Gen=0, BC=1, SC=2, ST=3),

EDN = Education of the household-head (completed years of schooling),

AGE = Age of the household-head (in completed years),

LHOLD = Landholding (ha),

FAMSIZE = Family size (No.),

PPC = Cost of plant protection chemicals (Rs/ha),

SEED = Cost of seeds (Rs/ha),

LABOUR = Cost of labour (Rs/ha),

YIELD = Yield of Bt cotton (q/ha),

b_j = Logit coefficients (j = 0,1...,9), and

U_i = Random disturbances (i=1,2…,60).

Results and Discussion

Input Utilization, Cost and Yield in Bt and Non-Bt Cotton Cultivation

The average landholding size of Bt cotton farmers was 3.33 ha, while that of non-Bt cotton farmers was 2.93 ha (Table 6), most of which was rainfed (to the tune of 70% and 73%, respectively). The holding-size varied from 1.48 ha (small farmers) to 4.65 ha (large farmers) in the case of Bt cotton, while for their non-Bt counterparts, it correspondingly ranged from 1.18 ha to 4.10 ha. The area under Bt cotton ranged from 1.03 ha (small farmers) to 2.90 ha (large farmers), with an average of 2.21 ha, accounting for 66 per cent of the total landholdings. The area under non-Bt cotton was lower, varying from 0.96 ha to 2.20 ha with an average of 1.97 ha (67% of the total landholdings).

The average expenditure on seeds was higher (₹ 3718/ha) in Bt cotton than in non-Bt cotton (₹ 2550/ha) farms (Table 7), largely due to higher cost of Bt cotton seeds. It may be mentioned that Bt cotton (hybrid) seeds were initially sold at a price (₹ 1,650/450 gram), which was five-times that of the local hybrid variety DCH-32 (₹ 300/450 gram) (Acharya, 2006). The

Table 6. Average landholding of sample farmers

(ha)

Landholding particulars	Bt cotton farms				Non-Bt cotton farms			
	Small	Medium	Large	Overall	Small	Medium	Large	Overall
Irrigated	0.52	1.17	1.35	1.01	0.30	1.00	1.10	0.80
	(35.1)	(30.2)	(29.0)	(30.3)	(25.4)	(28.6)	(26.8)	(27.3)
Rainfed	0.96	2.70	3.30	2.32	0.88	2.50	3.00	2.13
	(64.9)	(69.8)	(71.0)	(69.7)	(74.6)	(71.4)	(73.2)	(72.7)
Total	1.48	3.87	4.65	3.33	1.18	3.50	4.10	2.93
Area under cotton	1.03	2.70	2.90	2.21	0.96	2.00	2.20	1.97
Per cent of landholding	70	70	62	66	81	57	54	67

Note: Figures within the parentheses are percentages of respective columns.

quantity of organic manure (tonnes) used in Bt (6.5/ha) and non-Bt (6.7/ha) farms was almost same. But, the cost incurred on chemical fertilizers and organic manure was higher in non-Bt (₹ 2605/ha) than Bt (₹ 2502/ha) farms.

The use of labour was more on non-Bt than Bt farms. It was due to more number of sprays for pest management on non-Bt cotton, adding to the cost on human labour. Qaim and Zilberman (2003) have observed that Bt hybrids received only one-third sprays against bollworm than that by non–Bt hybrids. Similarly, the use of organic manure and chemical fertilizers was higher for non-Bt cotton than Bt-cotton by about 0.2 t/ha and 27 kg/ha, respectively.

There was a significant difference in expenditure on plant protection chemicals (PPC) between Bt (₹ 6369/ha) and non-Bt (₹ 4394/ha) farmers. However, Bt farmers under the direct guidance of extension workers and scientists used the pesticide judiciously and thereby could reduce the expenditure on PPC to 11.6 per cent of the total cost as compared to 16.2 per cent by non-Bt farmers. This clearly indicated higher use of synthetic chemicals, which is hazardous to the human health and is an interference in the activities of beneficiary insects, which prey upon larvae. Ismael *et al.* (2002) have observed that during the early stages of adoption, Bt growers used more insecticides than needed. Bennett *et al*. (2004) have reported that the number of sprays required for the control of sucking pests was same for Bt and non-Bt cottons, but the number of sprays required for bollworm control was much lower for Bt-cotton, leading to reduction in the expenditure by 72 per cent in 2002. Similarly, several studies have reported considerable reduction in expenditure on PPC applications, namely, 70 per cent by Qaim and Zilberman (2003), 82 per cent by Huang *et al*. (2004), 35-48 per cent by Bennett *et al*. (2006), among others. In India also, mean insecticide reductions of around 50 per cent have been reported. Interestingly, Pemsl *et al*. (2004) have concluded that a prophylactic chemical control strategy would be superior to the use of Bt varieties in both irrigated and non-irrigated cotton in Karnataka.

The total cost of production (cost-D) per ha including interest on working capital, land revenue, depreciation charges, imputed value of family labour and marketing cost was worked out to be higher for non-Bt cotton (₹ 39304) than Bt cotton (₹ 36675). It was largely because of higher expenditure on more number of pesticide sprays in the case of non-Bt cotton. This cost increased with increase in the size of landholding in both Bt and non-Bt farms.

With a yield of 24 q/ha, the Bt farmers could realise an additional cotton yield of 5.60 q/ha (30.43%) over non-Bt farmers. Again interestingly, the yield levels were positively associated with landholding-size. In general, the genetically modified cotton hybrids in India improved yields by 29 per cent over the traditional seeds (GoI, 2005). Naik *et al.* (2005) have reported 34 per cent increase in yield in Maharashtra, Karnataka, Andhra Pradesh and Tamil Nadu in 2002-03, whereas Narayanamoorthy and Kalamkar (2006) have reported a yield increase of 52 per cent in Maharashtra in 2003-04.

Bt-farmers realized higher gross returns (₹ 67284/ha) as compared to non-Bt farmers (₹ 51493/ha), and in both the cases, as the farm-size increased, the gross

Table 7. Input utilization pattern, cost incurred and yield realized by farmers in Bt and non-Bt cotton

(Value in ₹)

Inputs	Bt cotton								Non-Bt cotton							
	Small farms		Medium farms		Large farms		Overall		Small farms		Medium farms		Large farms		Overall	
	Qty	Value	Qty	Value	Qty	Value	Qty	Value	Qty	Value	Qty	Value	Qty	Value	Qty	Value
Seeds (kg)	3.36	3710	3.44	3721	3.36	3725	3.38	3718	2.5	2050	3.0	2555	3.5	3045	3.0	2550
Labour																
a) Human labour (human days)	100	6005	100	6100	102.7	6135	101.3	6080	122	7415	124.5	7524	129	7665	125	7534
b) Bullock labour (Bullock pair days)	14.0	4400	14.7	4345	15.6	4530	14.7	4425	13.3	4240	15.0	4320	15.5	4565	14.6	4375
c) Machine labour (hours)	6.5	1950	6.5	1950	7.5	2250	6.8	2050	6.5	1950	7.0	2100	7.5	2550	7.0	2200
FYM (tonnes)	6.4	2425	6.5	2456	6.7	2470	6.5	2450	6.5	2350	6.6	2456	7.0	2700	6.7	2502
Fertilizer (kg)	243	2506	246	2515	247.8	2510	245.8	2510	265	2555	275	2610	276	2650	272	2605
PPC (Rs)		4350		4412		4422		4394		6340		6377		6390		6369
Int. on working capital (Rs)		2027		2039		2083		2049		2152		2235		2365		2250
Total variable cost (Rs)		27373		27538		28125		27679		29052		30177		31930		30385
Depreciation (Rs)		880		895		910		895		770		775		810		785
Land revenue (Rs)		50		50		50		50		50		50		50		50
Rental value of land (Rs)		3663		3790		4325		3926		3654		3675		4320		3883
Total fixed cost (Rs)		4593		4735		5285		4871		4474		4500		5180		4718
Family labour (Rs)		2125		2145		2180		2150		2500		2555		2580		2545
Marketing cost (Rs)		1975		1975		1975		1975		1656		1656		1656		1656
Cost of cultivation (Rs)																
a) Cost A		27373		27538		28125		27679		29053		30177		31930		30385
b) Cost B		31966		32273		33410		32550		33527		34677		37110		35105
c) Cost C		34091		34418		35590		34700		36027		37232		39690		37650
d) Cost D		36066		36393		37565		36675		37683		38888		41346		39304
Yield (quintal)		23.6		24		24.5		24		17.8		18.5		19		18.4
Gross returns (Rs)		66080		67200		68600		67284		49480		51800		53200		51493
Net returns (Rs)		30014		30807		31035		30618		11797		12912		11854		12189
Benefit-cost ratio		1.83		1.84		1.82		1.83		1.31		1.33		1.28		1.31
Additional cost over non-Bt (Rs)		-1617		-2495		-3781		-2631								
Additional return over non-Bt (Rs)		16600		15400		15400		15791								
Additional net return from Bt (Rs)		18217		17895		19181		18429								

returns also increased. Consistent with this finding, Narayanamoorthy and Kalamkar (2006) have observed in two districts of Maharashtra, that the net return was ₹ 31883/ha in Bt cotton as against ₹ 17797/ha in non-Bt cotton, implying an increase of 79 per cent.

The net returns over cost-D were much higher from Bt-cotton production (₹ 30618/ha) than from non-Bt cotton (₹ 12189/ha), accounting for an increase of 151 per cent. Across farm-size categories, the net returns per ha varied between ₹ 30014 and ₹ 31035 for Bt cotton and ₹ 11797 to ₹ 12912 for non-Bt cotton. The higher profitability of Bt cotton was also reflected in terms of benefit-cost ratio (1.83 in Bt cotton versus 1.31 in non-Bt cotton). Similarly, Dev and Rao (2008) have also reported that net income, farm business income, family labour income and farm investment income per acre were higher in Bt cotton by ₹ 1,806 (83%), ₹ 3,067 (146%), ₹ 2,088 (158%) and ₹ 2,785 (222%), respectively, over non-Bt cotton. Thus, the additional return to Bt over non-Bt was estimated at ₹ 15791/ha. The corresponding additional cost being negative (-₹ 2631), the net additional benefit from cultivating Bt cotton worked out to be ₹ 18429.

Therefore, Bt practices bring not only additional profits but also help in bringing stability in the ecosystem by reducing the use of chemicals. Hence, Bt technology is considered as eco-friendly, economical and socially acceptable, particularly in cotton cultivation. Bt crops pose no significant risks to the environment or to human health, and that their positive externalities exceed the potential negative ones (Shelton *et al*., 2002). Flannery *et al*. (2004) have carried out a cost-benefit analysis of the hypothetical cultivation of four GM crops in Ireland including a cost which is estimated as a levy of up to • 25/ha of GM crop cultivated. Findings have shown a higher gross margin per ha for all the GM crops than for their conventional counterparts reaching • 223/ha for GM HT sugarbeet.

Response Functions for Bt and Non-Bt Cotton Production

The production function with intercept dummy for Bt cotton technology was a "good fit" with all the explanatory variables included in the model collectively explaining nearly 79 per cent of the variation in the production (Table 8). Across all the three production functions (Bt, non-Bt and pooled), seed was a significant factor influencing production at 1 per cent probability level. The machine hours used had significant and positive influence on Bt cotton production. The intercept dummy used for Bt technology was significant at 1 per cent probability level, thus indicating that there was a structural break in the production function due to the introduction of Bt technology in cotton.

The sum of output elasticities in the case of Bt cotton production (1.19) was more than one, indicating increasing returns to scale which was mainly due to significant influence of seeds, organic manure, inorganic fertilizers, machine labour and human labour. The increasing returns to scale clearly revealed that there was scope to increase Bt cotton production by increasing the above inputs. In the case of non-Bt cotton farms, the sum of output elasticities (0.77) was less than one, indicating a decreasing return to scale. Hence, there was no scope to increase non-Bt cotton production by increasing other inputs. Therefore, the Bt cotton technology needs to be extended to those farmers who have not adopted it so far, through extension activities and other measures. This would, on one hand, cut down the plant protection costs of non-Bt cotton farmers and on the other, increase their cotton yields through improved protection and efficient use of other resources. Therefore, concentrated efforts need to be made to encourage the farmers to adopt Bt cotton to get higher benefits.

The regression co-efficient for the intercept dummy variable was positive and significant (0.266*). This implied that the parameters governing the input-output relations in the case of Bt cotton farms were different from those of non-Bt cotton farms. Thus, the results provided the necessary proof for decomposing the total change in per ha output with the adoption of Bt cotton technology. This result is in conformity with those of Hugar and Patil (2007), wherein the regression co-efficient (0.24*) for intercept dummy variable was significant. Similar results were obtained by Bisaliah (1977) for Punjab wheat economy, Kunnal (1978) for sorghum economy in the Hubli taluka of Dharwad district in Karnataka and Hugar *et al*. (2000) for IPM technology in cotton.

Ratios of Marginal Value Product to Marginal Factor Cost in Bt and Non-Bt Cotton Production

The ratios of marginal value product (MVP) to marginal factor cost (MFC) was computed for each of

Table 8. Production function estimates of Bt and non-Bt cotton production systems

Particulars	Symbol	Bt	Non-Bt	Pooled
No. of observations	n	30	30	60
Intercept	a	0.8517	2.2397	4.3967
		(1.3060)	(3.8892)	(0.8910)
Seeds (kg)	S	0.6881***	0.7921***	1.2269***
		(0.2207)	(0.2069)	(0.1365)
Farm yard manure (tonnes)	F	0.1447	-0.0416	0.1582
		(0.1306)	(0.1012)	(0.0929)
Chemical fertilizer (kg)	C	0.1384	-0.1337	-0.0703
		(0.2497)	(0.4097)	(0.2326)
Plant protection chemicals (Rs)	P	-0.0020	-0.0326	-0.0650
		(0.0540)	(0.3552)	(0.0502)
Human labour (human-days)	H	0.1146	0.1925	-0.4009
		(0.2449)	(0.1862)	(0.1230)
Bullock labour (bullock pair days)	B	-0.2313	-0.0057	-0.1378
		(0.2030)	(0.1820)	(0.1600)
Machine time (hours)	M	0.3404**	0.0020	0.0858
		(0.1520)	(0.0850)	(0.0888)
Intercept dummy for Bt technology	D			0.2663***
				(0.0751)
Returns to scale (b_i)		1.1929	0.7730	0.7970
Coefficient of multiple determination	R^2	0.6472	0.4600	0.7883
Adjusted R^2	$\bar{R}^2$	0.5296	0.2800	0.7592
F value	F	5.5036	2.5554	27.1256

Note: ******* and ****** indicate significance at 1 per cent and 5 per cent probability levels, respectively.
Figures within parentheses indicate standard errors of coefficients.

Table 9. Ratios of MVP to MFC in Bt and non-Bt cotton farms

Resources	MVP/MFC ratio		Resource-use efficiency	
	Bt cotton	Non-Bt cotton	Bt cotton	Non-Bt cotton
Seeds	12.440	16.020	Underutilization	Underutilization
FYM	3.973	-0.858	Underutilization	Excessive utilization
Fertilizers	3.709	-2.647	Underutilization	Excessive utilization
Plant protection chemicals	-0.031	-0.264	Excessive utilization	Excessive utilization
Human labour	1.268	1.318	Underutilization	Underutilization
Bullock labour	-3.517	-0.067	Excessive utilization	Excessive utilization
Machine labour	11.280	0.047	Underutilization	Underutilization

Note: MVP=Marginal Value Product; MFC=Marginal Factor Cost.

the factors of production to draw some inferences about the resource-use efficiency (Table 9). For PPC and bullock labour, the MVP to MFC ratios were negative implying that these resources were being used excessively. Interestingly, the MVP to MFC ratio was negative in both Bt (-0.0306) and non-Bt cotton (-0.2641), which clearly indicated the excessive use of PPC. This was mainly due to use of more sprays in Bt cotton for control of sucking pests and in non-Bt cotton for control of mainly bollworm. While in the case of farm yard manure and chemical fertilizers, it was positive in Bt and negative in non-Bt cotton production.

The non-Bt cotton farmers used chemical fertilizers, organic manures and bullock labour excessively which resulted in lower returns. Therefore, the farmers cultivating non-Bt cotton with conventional practices of plant protection measure need to be educated about the ill-effects of excessive and indiscriminate use of chemical pesticides on both the production and income. Hugar and Patil (2007) have observed that the plant protection measures significantly influenced the Bt cotton yield, while these were negative and non-significant in the case of non-Bt cotton.

Sources of Productivity Difference between Bt and Non-Bt Cottons

Decomposition analysis was used to estimate the contribution of various sources to the productivity difference between Bt and non-Bt cottons. The decomposition analysis showed that the per ha production of Bt cotton was 26.38 per cent higher than that of non-Bt cotton (Table 10). The Bt technology component alone contributed 26.56 per cent to the total change in output, while the contribution of all other inputs was found positive but to a small extent (0.32%). The major contributor amongst all the inputs to the productivity difference was the seed (7.39%). The only other input with positive but very low contribution was the PPC (0.08%). The effectiveness of Bt technology in timely control of insect pests has led to the increase in cotton output. The plant protection chemicals and bullock labour were found to be negatively contributing to the total gross returns, due to high negative magnitude of their input efficiencies. This was consistent with the observation of Hugar and Patil (2007) that the per acre production of Bt cotton was 16.64 per cent higher than that of non-Bt cotton. The Bt cotton technology has alone contributed to the tune of 32.73 per cent to the total change in output, while the contribution of all other inputs was found to be negative (-16.14%).

Table 10. Estimated difference in output between Bt and non-Bt cotton farms

Particulars	Per cent
Total observed difference in output	26.38
Sources of output growth	
1. Technology component	26.56
a. Neutral component	-138.81
b. Non-neutral component	165.37
2. Input contribution	0.32
a. Seeds	7.39
b. Farm yard manure	-0.38
c. Fertilizer	-1.43
d. Plant protection chemicals	0.08
e. Human labour	-2.48
f. Bullock labour	-0.21
g. Machine	-2.65
Total estimated difference in output	26.88

Logit Model for a Farmer's Decision on Adoption of Bt Technology

The estimates of the logit model (Table 11) revealed that the decision of a farmer on adoption of Bt technology was positively influenced by his age, education, family size and yield of Bt cotton. On the other hand, the negatively influencing factors were caste, landholding-size, plant protection chemicals and labour cost.

Table 11. Logit model for a farmer's decision on adoption of Bt cotton technology

Variables	Coefficient (b_j)
CST	-4.707
EDN	9.814
AGE	.213
LHOLD	-1.100
FAMSIZE	5.550
PPC	-19.770*
SEED	-.726***
LABOUR	-6.760
YIELD	17.050***
Constant	-338.380
No. of observations (n)	60

Note: *** and * indicate significance at 1 per cent and 10 per cent probability levels, respectively.

Only 3 out of the 9 variables included in the model were significant. Seed cost and yield of Bt cotton were significant at 1 per cent probability level, whereas PPC was significant at 10 per cent level. All other variables included in the model were non-significant. Fernandez-Cornejo *et al*. (2001) had indicated that the effect of education on Bt hybrid adoption and on the likelihood of Bt hybrid adoption was positive and significant. The study had further indicated that the farm-size had a positive influence on the expected adoption of Bt hybrid, but its effect was not significant on the adoption of hybrid eggplant.

Table 12. Factors constraining adoption of Bt technology by non-Bt farmers

Particulars	No. of farmers (n= 30)	Percentage
Non-availability of quality Bt seeds	25	83
Non-availability of desired quantity of Bt seeds	21	70
Low adoption by neighbourhood farmers	13	43
No belief in Bt technology	11	37
Difficult to adopt Bt technology	9	30
Aware about Bt technology but not confirmed	7	23
Not aware about Bt technology	3	10

Amongst the significant variables, PPC and seed cost were found to negatively influence the farmer's decision on adoption of Bt technology. On the other hand, yield of Bt cotton positively and significantly influenced the probability of a farmer's decision to adopt Bt technology. However, the individual estimated parameters should be interpreted with caution (Bagi, 1984), because the dependent variable in the model is the logarithm of 'odds' of choice and not the actual probability.

Factors Constraining Adoption of Bt Technology

The factors constraining adoption of Bt cotton technology as perceived by the cotton growers, are presented in Table 12. Non-availability of quality Bt-seeds was the most important constraint hindering adoption of Bt cotton production technology, as opined by nearly 83 per cent of the farmer respondents. Wherever quality seeds were available, quantity was the limiting factor; in the sense, required quantity of seeds was not available.

The other reasons constraining Bt cotton production technology adoption were low adoption by neighbourhood farmers, no belief in Bt technology, difficulty in adoption of Bt technology, awareness about the technology but non-confirmation of its profitability and non-awareness about the Bt technology, in that order.

Qayum and Sakkhari (2003) have found that Mahyco-Monsanto Bt cotton was inferior to non-Bt cotton in terms of yields; pesticide use was negligible for both types of cotton; non-Bt farmers had higher profits and lower costs of cultivation, and suspected Bt cotton of a root rot that affected their soils for subsequent crops. Bt cotton has failed on many counts and the claims made by the company were wrong. Chaturvedi *et al*. (2007) have observed that the role of Indian Council of Agricultural Research (ICAR) was minimal in the case of Bt hybrids, unlike in the case of other crop varieties wherein ICAR used to conduct region-wise agronomic trials and advise the farmers on the best ones. This had left the farmers susceptible to any biased claims from the various companies involved, and more exposed to the vagaries of market forces.

Farmers' Perceptions on Various Dimensions of Impact of Bt Technology

The farmers' perceptions on the impact of Bt cotton technology on various dimensions were ascertained and analysed in terms of "positive", "neutral" and "negative" and the results have been presented in Table 13. On the yield front, farmers perceived that the Bt cotton technology had a very high positive impact on the yield of main product. On the contrary, they were not very confident that the technology provided cost reduction. Amongst all the environmental factors, pest and disease incidence was greatly influenced by the Bt cotton technology. While on the issue of impact on beneficial insects, farmers were indecisive.

Under the category of social-economic factors, farmers opined that there was a positive and significant impact of Bt technology on their farm income (94%), standard of living (87%), educational level (77%), employment (70%) and equity (60%). Shelton *et al*. (2002) have suggested that environmental and health risks need to be considered in a comprehensive impact assessment and that Bt crops pose no significant risks to the environment or to human health, and that their positive externalities exceed the potential negative ones.

Amongst several other dimensions of impact, the sustainability of resource use and quality of output of

Table 13. Farmers' perceptions about impact of Bt technology

(% of sample respondents)

Impact indicators*	Positive	Neutral
Yield enhancement		
Main product	80	20
By-product	30	70
Cost reduction	37	63
Improvement in environmental factors		
Soil texture	17	83
Soil moisture/Water demand	14	86
Soil/Water quality	20	80
Soil micro flora	7	93
Pests and diseases	80	20
Impact on beneficial insects	50	50
Improvement in farm level social-economic factors		
Standard of living	87	13
Farm income	94	6
Educational level	77	23
Employment	70	30
Equity	60	40
Enhanced sustainability in resource use	57	43
Saving of time/season	40	60
Improvement in quality of output		
Main product	84	16
By-product	70	30
Complementary enterprise/ resource use	40	60
Eco-friendliness	37	63

*There was no negative perception about any indicator

main product as well as by-product were reported to be positively influenced by the introduction of Bt cotton technology.

Genetic engineering is commonly offered as a hope to improve crop production efficiency by enhancing crop tolerance to various abiotic stresses such as drought, salt and water (Wang *et al*., 2003). Hossain *et al*. (2004) have estimated the potential impact of Bt eggplant technology on farmers' health through reduced insecticide exposure. Studies on Bt cotton in different countries have found that reduction in insecticide sprays was associated with a decrease in pesticide poisonings. Fruit and shoot borer (FSB) larvae possess all these specific conditions and therefore succumb when they feed on Bt brinjal (Manjunath, 2007). Bt brinjal does not harm or pose any threat to higher order organisms and non-target organisms as they lack specific receptors and conditions for activation of Bt protein in their gut. So, Bt brinjal is safe for consumption by all non-lepidopteron insects, birds, fish, animals and human beings. Owing to its in-built insect resistance and specificity, Bt technology is regarded as a superior technology for control of target pests, in this case FSB.

Conclusions and Policy Implications

More than 5 million farmers in India plant nearly 8 Mha of Bt cotton in the country, equivalent to 82 per cent of the total cotton area. Due to adoption of Bt cotton, on an average, the yield has increased by 31 per cent, insecticide application has decreased by 39 per cent, and profitability has increased by 88 per cent. The Indian Government has approved 263 Bt cotton hybrids till 2007-08. The states of Maharashtra, Andhra Pradesh, Gujarat, Punjab, Haryana, Rajasthan, Madhya Pradesh and Karnataka are the major cultivators of Bt cotton. In Karnataka, the Haveri district has topped the list in Bt cotton cultivation, followed by Belgaum, Raichur, Mysore, Gulbarga, Dharwad and Uttara Kannada. The empirical estimates of the benefits of Bt cotton cultivation have been few and far between. The present study has assessed the performance Bt technology and its impact on farming community of northern Karnataka.

On an average, per farm, the area under Bt cotton has been found 2.21 ha, accounting for 66 per cent of the total landholding. With a yield of 24 q/ha, Bt cotton has registered 31 per cent higher yield and 151 per cent higher net return over non-Bt cotton, the net additional benefit being ₹ 18429/ha. Bt cotton has offered increasing returns to scale. The non-Bt cotton farmers use chemical fertilizers, organic manures and bullock labour excessively which result in lower returns. Therefore, the farmers cultivating non-Bt cotton with conventional practices need to be educated on the ill-effects of excessive and indiscriminate use of chemical pesticides.

Technology has been the major contributor to the total productivity difference between Bt and non-Bt cottons. Seed cost, yield of Bt cotton and cost of plant protection have greatly influenced the probability of adoption of Bt cotton. Non-availability of quality seeds and in required quantity have been identified as the most important factors constraining Bt technology adoption. The impact of Bt cotton, as perceived by the farmers, has been in terms of enhanced yield, reduced pest and disease incidence, increased income, employment, education and standard of living and reduced health risk. To foster adoption, availability of quality and quantity of Bt cotton seeds to farmers needs greater attention of development agencies while research attention is called for incorporating resistance/ tolerance to *Spodoptera* and pink bollworms.

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