The Adoption and Economics of Bt Cotton in India: Preliminary Results from a Study

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Abstract

The paper presents preliminary results from a study of the economics and adoption of Bt cotton in India. Biotech crops, which made their appearance in the world about a decade ago, have gained substantial popularity and acceptance in many parts of the world including US, China, Australia, Mexico, Argentina and South Africa. However, their introduction in India has been relatively late and controversial and they still have considerable ground to cover in the country. Cotton is a major commercial crop in India but has substantial problems particularly from extensive pest damage and poor yields. Bt cotton offers a promising solution to these serious problems. Data from the survey, which covered the important cotton states of Gujarat, Maharashtra, Andhra Pradesh and Tamil Nadu, and 694 farmers, indicates that Bt cotton offers good resistance to bollworms as well as several other pests. The incidence of these pests is reported to be considerably lower in Bt cotton as compared to Non-Bt cotton. The yields of Bt cotton are found to be higher and the yield increase/ difference statistically significant in all the states under both irrigated and rain-fed conditions. As a result, given the good market acceptance of the product, the value of output per hectare is higher in all the states and conditions. The question of higher cost of cultivation exists, and is confirmed, mainly because of high seed cost and not commensurate reduction in pesticide cost. However, the profit is found to be higher in all the states to the estimated extent of about 80-90 percent on an average when the effects of associated inputs are included. The returns are highest in Maharashtra followed by Gujarat and then Andhra Pradesh. Subjective assessment indicates that farmers see advantage in Bt cotton in pest incidence, pesticide cost, cotton quality, yield and profit. Almost all farmers indicate that they plan to plant Bt cotton in the future. To increase the benefits from the technology, the farmers strongly urge reduction in the seed cost, greater field extension and demonstration work on the correct practices, and more Bt cotton varieties to suit the diverse agro-ecological settings.

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INTRODUCTION

Major advances in biotechnology have made it possible to directly identify and isolate genes, know their functions, and transfer them from one organism to another. These developments which have spanned the entire biological sciences have also had many applications for increasing plant productivity, improving plant resistance to diseases and pests, and improving the quality of the output. It has now been a decade since their introduction into field implementation since the mid-nineties.

Cotton is a major cash crop of India. It is grown under rainfed as well as irrigated conditions and the major cotton producing states include Maharashtra, Gujarat, Andhra Pradesh, Punjab, Karnataka, and Madhya Pradesh. The productivity of cotton in India is, however, very low. The pest problem in cotton is one of the worst among all crops. The main pest is boll worms and the largest quantity of pesticides among all crops is applied to control pests in cotton – often with little success. Cotton cultivation had recently become uneconomic in many parts of the country due to the high cost of pesticides and the low yields. It is under this background, and after much government hesitation, that the introduction of Bt cotton took place in India in 2002.

BACKGROUND OF BT COTTON IN THE WORLD

Since the introduction transgenic crops in 1996, there has been a substantial increase in their area (Chaturvedi, 2002). The Monsanto company developed Bt Cotton (*Bacillus thuringiensis* Cotton) and this is now one of the widely grown transgenic crops. It is currently grown in a large number of countries, including United States, China, India, Australia, Argentina, South Africa and Indonesia.

Bt cotton contains a foreign gene obtained from *Bacillus thuringiensis,* which is an aerobic bacterium characterized by its ability to produce crystalline inclusions during sporulation. This bacteria was first discovered by Japanese bacteriologists in 1901 and subsequently in 1915 a German scientist isolated the crystal toxin in Thuringen region of Germany. *B. thuringiensis* was registered as a microbial pest control agent in 1961 under the Federal Insecticide and Rodenticide Act in the US. In India Bt formulations have been registered under Pesticides Act 1968.

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With the advent of biotechnology, this bacterial gene has been introduced genetically into the cotton seeds, and it protects the plants from bollworms, a major pest of cotton. The worms feeding on the leaves of a Bt cotton plant become lethargic and sleepy and are gradually eliminated.

Many countries have reported positive experiences with Bt cotton. This includes USA, China and Australia. Bt cotton has spread very rapidly in China. There is good demand for it from the farmers since it reduces the cost of pesticide applications as well as the exposure to pesticides. In China the government has played a major role in providing GM technology to the farmers (Pray, EC, et al, 2002). The chronological progress of adoption of Bt cotton across countries is shown in Table 1. Commercial cultivation of Bt cotton has taken in US, Australia and Mexico in 1996, and by China and South Africa after a lag of one year. Countries such as India, Indonesia and Colombia have taken up its commercial cultivation much later, since 2002. Table 2 shows that the area under Bt cotton has increased from 0.8 million hectare during 1996 to almost 6 million hectares by the year 2003.

Table 1 : Adoption of Bt Cotton in Major Cotton Growing Countries

Country	1996	1997	1998	1999	2000	2001	2002	2003
USA	√	√	√	√	√	√	√	√
Australia	√	√	√	√	√	√	√	√
China		√	√	√	√	√	√	√
India							√	√
Indonesia							√	√
Mexico	√	√	√	√	√	√	√	√
Argentina			√	√	√	√	√	√
Colombia							√	√
South Africa		√	√	√	√	√	√	√

Source: James C (2003), Preview: Global Status of Commercial Transgenic Crops:2003, ISAAA Brief No. 30, Ithaca, NY

Table 2: Global Adoption of Bt Cotton (Million Hectare)

Year	Bt Cotton	Bt and HT Cotton	Total
1996	0.8	0.0	0.8
1997	1.1	.1	1.2
1998	1.4	.1	1.5
1999	1.3	0.8	2.1
2000	1.5	1.7	3.2
2001	1.9	2.4	4.3
2002	2.4	2.2	4.6
2003	3.1	2.6	5.7

Source: James C (2003), Preview: Global Status of Commercial Transgenic Crops:2003, ISAAA Brief No. 30, Ithaca, NY

COTTON PRODUCTION IN INDIA

India is unique in that all four major cultivated species of cotton are grown here commercially. The distribution is shown in Table below:

Table 3: Species Composition of Cotton in India
Area (million hectare)

Species	Variety (Non-Hybrid)	Hybrid
Hirsutum	2.7	3.2
Arboreum	1.6	<0.05
Herbaceum	0.6	Nil
Barbadense	Nil	1.0
Total	4.9	4.0
Source: Mayee and Rao (2002)		

The cotton produced is of 4 different qualities: Medium staple; Superior medium staple, Long staple and Extra long staple. The distribution of the consumption and the future requirement are shown in the Table below:

Table 4: Distribution of Consumption and Requirement of Cotton in Different Staple Groups
(in percent)

Staple length group	Consumption (1996-97)	Projected Requirement in 2004-05	
		By CIRCOT	*By SITRA*
Medium staple	48	46	38
Superior medium staple	18	12	19
Long staple	29	38	39
Extra Long staple	5	4	4
Total	100	100	100
Total Quantity (lakh bales)	150.4	192	205
Source: ICMF Annual Report 1997/98			

The ushering in of Hybrid cotton era brought about a substantial increase in cotton production. Development of Hybrids such as Hybrid 4, JKHY 1, NHH 44 and DCH 32 brought about a white revolution in cotton. Similarly, the development and release of varieties such as LRA 5166, MCU 5, Suvin and hybrids like DCH 32, H 6 and Savitha brought about a qualitative change in Indian cottons. The varieties recommended by the Cotton Advisory Board are given in table below:

Table 5 : Varieties and Hybrids Recommended by Cotton Advisory Board				
	Qualities			
	0-20s < 25 mm	21s-40s 25-29 mm	41s-80s 29-34 mm	81s and above > 34 mm
Varieties and Hybrids	RG.8 LD.491 B.N./F. 1378 LH.1558 H.1098 Jawahar Tapti G. Cot.17 G. Cot.21 / V.797 /G. Cot.13 Jayadhar Suyodhar	LRA.5166 AKA.8401 NHH.44 NHH.302 H.8 G. Cot.16 DHH.11 LRK.516 S.6 Sahana LHH.144	Bunny H.6 / S.6 MCU.5	DCH.32 MCU.5 Suvin Surabhi

With cultivation on around 9 million hectares, India's cotton acreage is the largest in the world and India is the third largest cotton producer after US and China. The analysis given below indicates that the cotton production has nearly doubled in the green revolution period from 5.78 million bales in 1967/68 to 10.09 million bales in 2001/02 (bale=170kg). However, the Figure 1 below shows that the production fluctuates a lot. The annual growth rate is 2.51 percent over these years, and most of the growth appears to have come from yield growth, which shows a growth rate of 2.13 percent. However, in the last 10 years the production growth rate shows deceleration to –0.38 percent and much of this is due to decline in the yields, which show a growth rate of –2.34 percent, indicating a problem with the existing technology. However, the area growth rate has accelerated to 2.02 percent in this period indicating that the crop is finding favour with the farmers. The figures and growth rates for/ upto the recent year of 2004/05 indicates a revival in the yields and production of cotton which may be related to the introduction of Bt cotton.

Table 6: Cotton: Performance			
Year	Area (m ha)	Yield (kg/ha)	Production (million bales of 170 kg each)
1967/68	8.00	123	5.78
1981/82	8.06	166	7.88
1990/91	73.9	269	11.70
1991/92	7.66	216	9.71
2001/02	9.10	189	10.09
2004-05 (P)	8.97	404	21.30
Annual Growth Rates			
1967/68-2001/02	0.373	2.134	2.513
1981/82-2001/02	1.092	1.599	2.704
1991/92-2001/02	2.020	-2.341	-0.381
1990-91-2004-05	0.77	1.70	2.47

Even though India ranks first in area in world, it occupies only the third position in production and nearly the last position in productivity. Nearly 65 per cent cotton cultivation is rain-dependent and subject to heavy vagaries of monsoon rains. Continuous presence of cotton in the subcontinent makes it easy for pest, diseases and other biotic stress agents to survive, multiply and cause frequent epidemics (Mayee, 2002). The cotton fiber accounts for almost 73 per cent of the total raw material mix of the textile industry. The research programs undertaken by Cotton Institutes, Agricultural Universities and ICAR over the past decades have led to significant improvements in terms of quality and quantity of cotton. The country is by and large able to meet the demand of different quality cottons through a wide range of hybrids and varieties developed in the system (Cotton: A March Towards New Millennium, 2001).

In India, cotton is grown mainly in nine states spread over three zones, the north, central and south, see Figure 2 below. The yield of cotton varies substantially from about 430 kg. per hectare in Punjab and Haryana to 100 to 125 kg. per hectare in Gujarat and Maharashtra. Outbreak of American Bollworm in epidemic proportion during crop season of 2001 resulted in very heavy damage to cotton crop, especially in the North zone, which recorded as much as 20-50 per cent reduction in yield compared to the previous year. However, the loss in production in the North Zone was more than compensated by above normal crops in Maharashtra and Gujarat. The cotton cultivation in India has been plagued with rising cost of cultivation, ineffective pesticides, adulterated seeds, and other inputs, leading to frequent crop failures (Bose, 2000).

Figure 1: Cotton Production

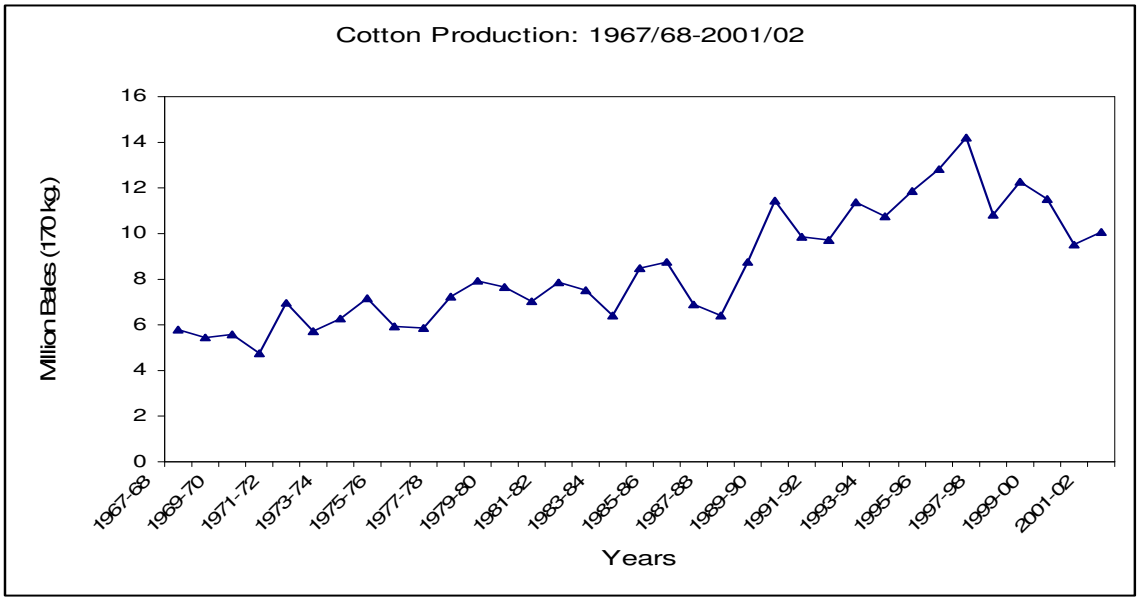
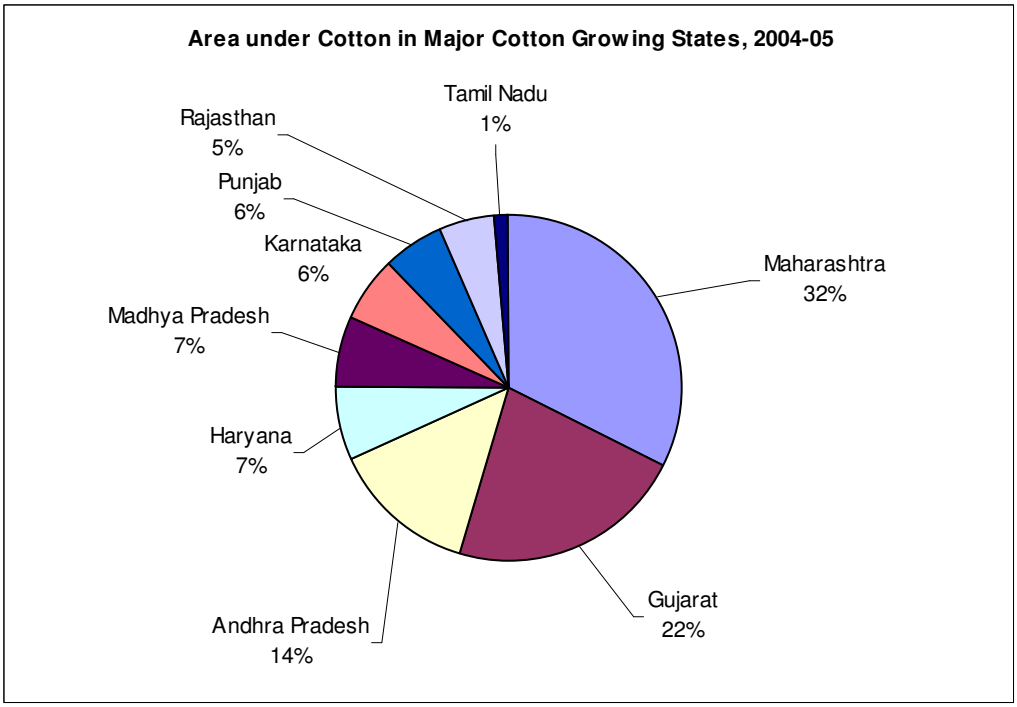


Figure 2: Distribution of Cotton Area by State



The cotton crop is highly susceptible to insect pests. About 166 different species of insect pests are reported to attack cotton at various stages of its growth. Among these, the cotton bollworm, whitefly, jassids, pink bollworm and spotted bollworm have been causing substantial economic damage to cotton crops all over the country. The pests and diseases cause more than 50 percent damage to cotton crop in India compared to 24.5 percent world over. About 96,000 metric tons of technical grade pesticides are currently produced in the country of which 54 percent are consumed on cotton. Therefore, suitable low cost and effective pest and disease management methods are needed. Integrated pest management (IPM) that focuses on prevention of pests and their damage through an integrated approach of multiple pest suppression techniques needs to be vigorously promoted. Bt Cotton offers another major option. It is estimated that India loses about Euro 300 million per year to the boll worm, besides the annual cost of pesticides application on cotton is over Euro 350 million (Bio-scop.org, 2004).

Bt Cotton in India

The Government of India allowed the production of three genetically modified Bt cotton hybrids for three years from April 2002 to March 2005. This followed the controversial unauthorized release and cultivation of Bt cotton in some areas in the previous year. The authorized cotton varieties are Bt MECH 162, Bt MECH 184, and Bt MECH 12. By 2002/03, officially Bt cotton has been grown in about 1 lakh hectares in Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra and Tamil Nadu. Unofficial use, especially in Gujarat is said to be quite large.

Even though the performance of Bt cotton has been projected to be satisfactory in some circles, there is great discontent in different quarters with the variety. Some indicate that the variety is susceptible to the bollworm and the yield is below par (K. Venkateshwarlu 2002). The study indicated that Bt Cotton has failed on many counts and the claims made by the company were wrong. It neither improved yield through better plant protection nor reduced the pesticide usage and the returns were less since the pods were small, seeds were more, lint and the staple length were less (K. Venkateshwarlu, 2002). The price of Bt cotton was reported to be 10 per cent less in the local market (Business Line, 2002). In some cases, the new pests and diseases emerged, and Bt cotton failed to prevent even the boll worm attack. Some reports indicated that initially Bt Cotton showed resistance to boll worms but as soon as the formation of bolls started, the worms started attacking them (RFSTE, 2002). Despite these concerns, Bt cotton cultivation is spreading steadily and farmers in developing countries are also willing to adopt this technology to reduce the pest damage and the cost of production with due consideration for the environment (Iyengar and Lalitha, 2002).

According to official estimates, the area under Bt cotton in India is about 1 million hectare, or about 11 percent of the total area under cotton in the country, see Table 8 below. As of 2005, the share of area under Bt cotton to total area under cotton was over 27 percent in Madhya Pradesh, and about 18 percent in Maharashtra.

Table 7: Growth in Area under Bt Cotton in India : 000 ha						
State	2003	2004	2005	Area under Bt cotton as percent of total area under Cotton		
				2003	2004	2005
Andhra Pradesh	5.46	71.22	90.41	0.65	6.07	9.30
Madhya Pradesh	13.35	86.12	136.21	2.26	14.95	21.45
Gujarat	41.68	125.92	149.25	2.53	6.61	7.19
Maharashtra	21.85	161.47	508.67	0.79	5.42	17.61
Karnataka	3.04	34.30	29.34	0.97	6.70	8.08
Tamil Nadu	7.69	11.99	17.02	7.46	8.45	11.34
Punjab			70.42	0.00	0.00	12.14
Haryana			10.77	0.00	0.00	1.80
Rajasthan			2.31	0.00	0.00	0.51
Total	93.08	491.02	1014.40	1.22	5.50	11.51
Source: Indiastat.com						

In view of the controversy, the importance of cotton, the severe pest problem, and the solution Bt Cotton offers, it is appears worthwhile to undertake a comprehensive and systematic analysis of the technology across areas and assess the economic returns.

STUDY DATA AND SAMPLE PROFILE

A farmer survey was conducted to examine the economics of Bt cotton vis-à-vis non Bt cotton during 2004. The sample comprised of 694 cotton growing farmers in the country spread over four major cotton states namely Andhra Pradesh, Gujarat, Maharashtra, and Tamil Nadu. Table 8 below shows the distribution of the sample across the states.

The sample sought to cover an equal number of Bt cotton and Non-Bt cotton farmers. There was a slight deviation from this in the state of Maharashtra on account of difficulty in finding Non-Bt farmers. However, a large number of Non-Bt farmers were covered. It also sought to cover small, medium and large farmers by landholding, and farmers with and without irrigation for cotton.

Table 8: Sample Size			
	Bt Cotton	Non-Bt Cotton	Total
Gujarat	90	90	180
Maharashtra	85	69	154
Andhra Pradesh	90	90	180
Tamil Nadu	90	90	180
Total	355	339	694

Within the states, the study sampled districts which were important for cotton growing, and provided some variety in the location type. The following districts were sampled based on this information: Gujarat – Rajkot and Vadodara districts; Maharashtra – Jalgaon and Buldhana districts; Andhra Pradesh – Guntur and Warrangal districts; Tamil Nadu – Salem and Perambalur districts.

The Table 9 below provides information on the place of cotton in these sample districts and states. Cotton is a major crop in the states of Gujarat, Maharashtra and Andhra Pradesh, and the figures indicate that it is a significant crop in almost all of the selected districts, having greater than average importance in each of the states. Cotton is less important in Tamil Nadu, but in relative terms the selected districts are known for cotton and hold greater than average importance for cotton across the districts.

Table 9: Importance of Cotton in the Selected Districts (2003-04)

	Area under Cotton (Hectares)	Gross Sown Area (Hectares)	Percent Area under Cotton	Percent of State Area under Cotton
Gujarat (27 Districts)				
Vadodara	158.10	564.10	28.03	9.63
Rajkot	168.11	733.90	22.91	10.24
Maharashtra (42 Districts)				
Buldhana	220.12	847.21	25.98	7.09
Jalgaon	403.00	1359.92	29.63	12.98
Andhra Pradesh (23 Districts)				
Guntur	98.63	729.81	13.51	12.28
Warrangal	109.47	508.33	21.54	13.63
Tamil Nadu (28 Districts)				
Salem	15.63	330.82	4.72	9.24
Perambalur	23.65	219.04	10.80	13.98

Table 10 below indicates that the overall average farm size of the sample household is 3.38 hectares. This is somewhat higher than the national average because cotton cultivation is typically in dryer locations where farm sizes are bigger. Between the states, Maharashtra shows the largest average farm size of 5 hectares per household, and Tamil Nadu shows the smallest farm at 2.40 hectares per household. The Bt cotton farmers are somewhat bigger with an average farm size of 3.73 hectares as compared to non-Bt cotton farmers, who have an average of 3.02 hectares.

Table 10: Average Farm Size: Operated Area per Household in Hectares			
	Bt Cotton	Non-Bt Cotton	Average
Gujarat	3.45	3.13	3.29
Maharashtra	6.06	4.04	5.05
Andhra Pradesh	2.92	2.62	2.77
Tamil Nadu	2.49	2.30	2.40
Average	3.73	3.02	3.38

VARIETIES GROWN, PEST INCIDENCE AND RESISTANCE

As indicate above there is a huge diversity of types and varieties of cotton grown in the country. Within the sample as well, a large number of different varieties have been indicated. In Bt cotton, in the state of Gujarat, the varieties are identified by the name of the company and include RCH, Mahyco and other non-confirmed. In Maharashtra, these include MECH 184, MECH 12, MECH 162, Rashi 2, the first three being Mahyco-Monsanto varieties, and the last one from Rashi Seeds (RCH). In Andhra Pradesh, the MECH, Rashi and non-confirmed varieties are seen. The non Bt varieties vary substantially by state and include Shankar and Vikram in Gujarat, Ankur and Bunny in Maharashtra and Bunny, Brahma and Satya in Andhra Pradesh.

Table 11 : Varieties grown		
State	Cotton Type	Varieties
Gujarat	BT	RCH, Mahyco, Other Non-confirmed
	Non-BT	Sankar, Vikram, Navbharat Deshi, Other deshi
Maharashtra	BT	MECH 184, MECH 12, MECH 162, Rashi 2, 2 MECH, MECH + Rashi
	Non-BT	Ankur, Banny, Ajit, Others
Andhra Pradesh	BT	Rasi, MECH, Other Non-confirmed
	Non-BT	Bunny, Super Bunny, Brhma, Satya, Attara, JK, Tagore, Bindu, Others
Tamil Nadu	BT	RCH-2 BT
	Non-BT	RCH-2 Non-BT

The most important reason for the adoption of Bt cotton is its resistance to pests, particularly boll worms, which can be a devastating problem for cotton. This information has been collected and is being analyzed for the study, and is currently available only for the state of Maharashtra, as given below. In the case of boll worms, including American, pink and spotted boll worms, no infestation is indicated in over 70 percent of the cases reporting, whereas such incidents are found in only 2-30 percent of the cases in non-Bt cotton. Only about 4-6 percent of the sample for Bt cotton reports moderate to heavy infestation, whereas this number is as high as 20-60 percent in non-Bt cotton. Surprisingly, there is also a difference in the sucking and foliage feeding pests, where the incidence is mainly none to light in the case of Bt cotton, whereas it is moderate to heavy in the case of non-Bt cotton. Thus Bt cotton seems to clearly provide a resistance to boll worms for a larger majority of farmers, and also to other pests for most of the farmers. However a small number of farmers indicate incidence of boll worms, particularly other kinds of boll worms.

Table 12: Pest/Insect Attack on Cotton: Response of Bt Cotton Growers: Maharashtra

	BT					***Non-BT***				
Pest/Insect	Per-cent repo-rting	Infestation reported				Per-cent repo-rting	Infestation reported			
		None	Light	Mode-rate	Heavy		None	Light	Mode-rate	Heavy
Bt Cotton										
A. Boll Worm										
1. American Boll Worm	96.47	74.39	21.95	3.66	0.00	11.76	30.00	50.00	20.00	0.00
2. Pink Boll Worm	87.06	75.68	20.27	4.05	0.00	61.18	3.85	36.54	30.77	28.85
3. Spotted Boll Worm	90.59	72.73	20.78	6.49	0.00	56.47	2.08	41.67	39.58	16.67
4. Others	18.82	50.00	6.25	18.75	25.00	56.47	4.17	41.67	35.42	18.75
B. Sucking Pests										
1. Thrips	96.47	4.88	56.10	35.37	3.66	11.76	30.00	0.00	20.00	50.00
2. Leafhopper	95.29	3.70	58.02	30.86	7.41	58.82	0.00	18.00	56.00	26.00
3. Whitefly	95.29	6.17	58.02	33.33	2.47	57.65	0.00	20.41	55.10	24.49
4. Others	3.53	33.33	0.00	66.67	0.00	60.00	1.96	19.61	47.06	31.37
C. Foilage Feeding Pests										
1. Leaf Roller	94.12	27.50	45.00	26.25	1.25	42.35	2.78	38.89	50.00	8.33
2. Caterpillar	89.41	27.63	40.79	28.95	2.63	40.00	2.94	29.41	61.76	5.88
3. Others	7.06	50.00	33.33	16.67	0.00	5.88	20.00	40.00	40.00	0.00
D. Soil Pests										
1. Termite	88.24	34.67	17.33	36.00	12.00	40.00	2.94	14.71	55.88	26.47

YIELDS AND PESTICIDE USE

Table 13 below indicates the performance of Bt cotton, relative to Non-Bt cotton in the reduction of pesticide use. The information shows that pesticides are still used by farmers after shifting to Bt cotton. However, there is a significant reduction in the number of sprays that are applied as well as the cost of pesticides. In Maharashtra, the average number of sprays is reduced from 5.28 to 3.37, a 36 percent reduction. The cost per hectare reduces by 21 percent. In the case of Andhra Pradesh, the average number of spray reduced from 8.11 to 4.27 with a

similar reduction in the costs. In the case of Tamil Nadu, the average number of spray reduces from 6 to 4 and the cost per hectare reduces by 50 percent. Thus, even though pesticide spraying is not eliminated, there is a substantial reduction in the pesticide use and the cost.

Table 13: Application of Pesticides in Bt and Non-Bt cotton

State		Bt Cotton	Non-Bt Cotton
Maharashtra	Average Number of Sprays	3.37	5.28
	Cost per ha (Rs.)	3242	4120
Andhra Pradesh	Average Number of Sprays	4.27	8.11
	Cost per ha (Rs.)	7926	10675
Tamil Nadu	Average Number of Sprays	4	6
	Cost per ha (Rs.)	1910	4195

The Table 14 below compares the performance of Bt and Non-Bt cotton in terms of their yield and value of outputs under irrigated and unirrigated conditions. The table shows that in all cases, the yields of Bt cotton are higher than the yields of Non-Bt cotton. This is found to be true under irrigated as well as unirrigated conditions. The yields obtained with irrigations are typically higher than those without irrigations, except in the case of Andhra Pradesh, where they are marginally lower for Bt cotton, perhaps because of the nature of the sample. For Non-Bt cotton, the yield as well as the value of output appear to be the highest in Andhra Pradesh followed by Gujarat, Maharashtra and Tamil Nadu in that order. Note that the Gujarat sample could not include unirrigated cotton since this was not to be found in the sample districts. In the case of Bt cotton under irrigation, the highest yield is found to be in Gujarat, followed by Andhra Pradesh, Maharashtra and Tamil Nadu in that order. In terms of value of outputs, Maharashtra is higher than Andhra Pradesh. The results indicate a sizeable impact of Bt cotton on the yield and value of output under both irrigated and unirrigated conditions.

Table 14: The yield and value of output from Bt and Non-Bt cotton

State		Bt Cotton			Non-Bt Cotton		
		Irrigated	Unirrigated	Total	Irrigated	Unirrigated	Total
Gujarat	Yield (Kg/Ha.)	3176		3176	2345		2345
	Value of output (Rs.)	61848		61848	44720		44720
Maharashtra	Yield (Kg/Ha)	2755	2410	2605	1856	1747	1780
	Value of output (Rs.)	57262	50487	54313	39948	38973	39270
Andhra Pradesh	Yield (Kg/Ha.)	2933	2961	2962	2793	1607	2049
	Value of output (Rs.)	49437	52847	50970	48810	28372	35870
Tamil Nadu	Yield (Kg/Ha.)	2375	1335	1893	1697	1210	1473
	Value of output (Rs.)	45599	29797	38282	29307	23632	26032

COSTS, RETURNS AND ECONOMICS

The Table 15 below provides the comparative information on the cost of production and returns of Bt and Non-Bt cotton across the different states. The table indicates that consistently the total cost is higher for Bt cotton as compared to Non-Bt cotton. Even though the pesticide cost is substantially lower, the seed cost is substantially higher in all cases, often 2 to 3 times higher. Besides this several other cost, such as labour, tractor and irrigation are also higher. However, the value of output is also greater under Bt cotton in all states. As a result the net profit is substantially higher with Bt cotton in all states.

Table 15: Cost of Production, Value of Output and Profit per hectare

	Gujarat		Maharashtra		Andhra Pradesh		Tamil Nadu	
	Bt	Non-Bt	Bt	Non-Bt	Bt	Non-Bt	Bt	Non-Bt
1. Human Labour	10784	9317	11754	9150	9818	8249	9089	7714
2. Bullock	2655	2568	1913	2125	2062	2024	0	0
3. Tractor	970	737	1016	748	1705	1648	2373	1734
4. Farm Yard Manure	1395	1424	0	0	2103	2000	2228	1325
5. Fertilizer	3254	3014	7116	4086	4804	4078	2922	3740
6. Seed	3111	1314	3857	1319	3313	1213	3977	1180
7. Pesticides	2586	3153	3242	4120	7806	10878	1909	4195
8. Irrigation	4497	4179	1136	474	319	163	55	60
9. Other Operational Costs			332	122				
10. Marketing Cost	626	580	1314	1181	210	192	487	312
11. Total Cost	29878	26287	31679	23207	32139	30444	23040	20260
Value of Output	61943	44531	54313	37524	50970	35870	38282	26032
Profit	32065	18244	22634	14317	18831	5426	15242	5772

The Table 16 below examines the cost structure in terms of the share of various costs in cotton production. The table indicates that human labour and fertilizers constitute a large share in the cost across the states. However, in Andhra Pradesh, the share of pesticides is very high. There is a significant reduction in the share of pesticide cost with the adoption of Bt cotton and the most dramatic reduction is seen in Tamil Nadu, where it drops from 20.71 percent to 8.29 percent. However, the seed cost in the same state increases from 5.82 percent to 17.26 percent. The share of pesticide cost remains very high at 24.29 percent even with Bt in Andhra Pradesh. Since with the impact on yield, the value of output, under Bt cotton is substantially higher, the profit as a percent of the revenue is also substantially higher in Bt as compared to Non-Bt. In Gujarat, this increased from 40.97 percent to 51.77 percent and in the case of Andhra Pradesh, it increases from 15.13 percent to 36.95 percent.

Table 16: Share of Various Inputs in Total Cost								
	Gujarat		Maharashtra		Andhra Pradesh		Tamil Nadu	
	Bt	Non-Bt	Bt	Non-Bt	Bt	Non-Bt	Bt	Non-Bt
1. Human Labour	36.09	35.44	19.39	20.48	12.54	12.87	23.50	25.47
2. Bullock	8.89	9.77	6.04	9.16	6.42	6.65	0.00	0.00
3. Tractor	3.25	2.8	3.21	3.22	5.30	5.41	10.30	8.56
4. Farm Yard Manure	4.67	5.42	0.00	0.00	6.54	6.57	9.67	6.54
5. Fertilizer	10.89	11.47	22.46	17.61	14.95	13.39	12.68	18.46
6. Seed	10.41	5	12.18	5.69	10.31	3.98	17.26	5.82
7. Pesticides	8.65	11.99	10.23	17.75	24.29	35.73	8.29	20.71
8. Irrigation	15.05	15.9	3.58	2.04	0.99	0.53	0.24	0.30
9. Picking(harvesting)*	0	0	17.71	18.95	18.01	14.22	15.95	12.61
10.Other Operational Costs	0	0	1.05	0.52	0.00	0.00	0.00	0.00
11. Marketing Cost	2.1	2.21	4.15	5.09	0.65	0.63	2.11	1.54
12. Total Cost	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Total Cost per ha in Rs.	29878	26287	31679	23207	32139	30444	23040	20260
Total Value of output per ha in Rs.	61943	44531	54313	37524	50970	35870	38282	26032
Profit per ha in Rs.	32065	18244	22634	14317	18831	5426	15242	5772
Profit as percent of Value	51.77	40.97	41.67	38.15	36.95	15.13	39.82	22.17

ANALYSIS OF PERFORMANCE, COST AND IMPACT

The adoption of Bt cotton would be closely related to its benefits to the farmers, and therefore it is important to examine the impact of Bt cotton on the economics of cotton cultivation. This has first been examined through a regression approach relating yield with a dummy variable of Bt cotton, which is 1 for Bt cotton and 0 for Non-Bt cotton. The results below indicate that Bt cotton clearly has a statistically significant impact on the yield, significant at the 99 percent level. The estimates indicate that Bt cotton yields are 30.71 percent higher. The impact of the value of output is also highly significant and estimates show that this is boosted by 33.35 percent. However, the cost also rise significantly, and this rise is estimated to be 6.69 percent. The pesticide cost is reduced by 23.98 percent, but the seed cost rises by 168.77 percent. The difference in the output price between Bt and Non-Bt cotton is positive but not statistically significant. The results indicate that the profit rise is highly significant and the increase is estimated to be 87.58 percent. The results explain the popularity of Bt cotton, at the same time, the opposition to the high seed cost.

Table 17: Regression Results: Impact of Bt Cotton				
		Independent Variables		N=515
Dependent Variable		Constant	Bt	Percent Impact of Bt
Yield	Coefficient	2212.25	679.45	30.71
	t-stat	47.05	10.37	
	Signifi.	***	***	
Value of Output	Coefficient	41861	13960	33.35
	t-stat	45.2	10.81	
	Signifi.	***	***	
Total Cost	Coefficient	28066	1878.56	6.69
	t-Stat	71.5	3.43	
	Signifi.	***	***	
Pesticide Cost	Coefficient	7387.95	-1771.47	-23.98
	t-Stat	33.01	-5.68	
	Signifi.	***	***	
Seed Cost	Coefficient	1296.12	2187.41	168.77
	t-Stat	28.71	34.76	
	Signifi.	***	***	
Price	Coefficient	19.04	0.28679	1.51
	t-Stat	140.45	1.52	
	Signifi.	***	NS	
Profit	Coefficient	13795	12081	87.58
	t-Stat	16.1	10.11	
	Signifi.	***	***	
Note: *** = significant at 99 percent, ** = significant at 95 percent, * = significant at 90 percent, NS = not significant				

The performance of Bt cotton varies from state to state. The results given below indicate that in Gujarat, the positive impact on yield and value of output is greater than the combined results, but the cost increase is also greater. The reduction in the pesticide cost is somewhat lower, but the increase in the seed cost is also lower. The pesticide cost as such is considerably lower than the combined case as shown by the value of the coefficient of the constant. The price increase is statistically significant but small, and the profit increase is 73.81 percent.

Table 18: Regression Results: Impact of Bt Cotton - Gujarat				
		Independent Variables		N=181
Dependent Variable		Constant	Bt	Percent Impact of Bt
Yield	Coefficient	2345.25	830.89	35.43
	t-stat	28.45	7.11	
	Signifi.	***	***	
Value of Output	Coefficient	44720	17128	38.30
	t-stat	26.27	7.09	
	Signifi.	***	***	
Total Cost	Coefficient	26318	3544.30	13.47
	t-Stat	38.26	3.63	
	Signifi.	***	***	
Pesticide Cost	Coefficient	3146.69	-568.64	-18.07
	t-Stat	16.99	-2.17	
	Signifi.	***	**	
Seed Cost	Coefficient	1346	1723.95	128.08
	t-Stat	13.36	12.07	
	Signifi.	***	***	
Price	Coefficient	18.96	0.4713	2.48
	t-Stat	114.7	2.01	
	Signifi.	***	**	
Profit	Coefficient	18402	13583	73.81
	t-Stat	14.33	7.46	
	Signifi.	***	***	
Note: *** = significant at 99 percent, ** = significant at 95 percent, * = significant at 90 percent, NS = not significant				

In the case of Maharashtra, the results given below indicate that the impact on the yield and the value of output is the highest among the three states, and the impact on the total cost is relatively low. Pesticide cost reduced by 22.38 percent, and the profit increase is the highest at 120.08 percent. This indicates that the technology may be highly profitable in Maharashtra.

Table 19: Regression Results: Impact of Bt Cotton - Maharashtra				
		Independent Variables		N=154
Dependent Variable		Constant	Bt	Percent Impact of Bt
Yield	Coefficient	1821	777.01	42.67
	t-stat	29.04	9.21	
	Signifi.	***	***	
Value of Output	Coefficient	38944	16663	42.79
	t-stat	25.29	8.04	
	Signifi.	***	***	
Total Cost	Coefficient	26198	1357.71	5.18
	t-Stat	31.63	1.22	
	Signifi.	***	NS	
Pesticide Cost	Coefficient	8241.22	-1844.21	-22.38
	t-Stat	22.96	-3.82	
	Signifi.	***	***	
Seed Cost	Coefficient	1319.28	2487.20	188.53
	t-Stat	38.42	53.81	
	Signifi.	***	***	
Price	Coefficient	21.36	-0.0415	-0.1943
	t-Stat	89.92	-0.13	
	Signifi.	***	NS	
Profit	Coefficient	12746	15305	120.08
	t-Stat	8.18	7.29	
	Signifi.	***	***	
Note: *** = significant at 99 percent, ** = significant at 95 percent, * = significant at 90 percent, NS = not significant				

In the case of Andhra Pradesh, the impact on the yields as well as the value of outputs is the lowest at about 21.33 percent, but the rise in total cost is also lower. The fall in the pesticide cost is the highest in Andhra Pradesh at -28.17 percent, but the rise in the seed cost is also the highest at 192.53 percent. This indicates why opposition to the seed prices may be the highest in Andhra Pradesh. The rise in the profits is statistically highly significant and amounts to a 78.18 percent, which is in between Gujarat and Maharashtra. The absolute level of profitability of cotton in Andhra Pradesh is lowest amongst the three states.

Table 20: Regression Results: Impact of Bt Cotton – Andhra Pradesh				
		Independent Variables		N=180
Dependent Variable		Constant	Bt	Percent Impact of Bt
Yield	Coefficient	2377.73	506.89	21.32
	t-stat	29.75	4.48	
	Signifi.	***	***	
Value of Output	Coefficient	41207	8789.63	21.33
	t-stat	30	4.52	
	Signifi.	***	***	
Total Cost	Coefficient	31266	1017.42	3.25
	t-Stat	80.09	1.84	
	Signifi.	***	*	
Pesticide Cost	Coefficient	11022	-3104.41	-28.17
	t-Stat	83.45	-16.62	
	Signifi.	***	***	
Seed Cost	Coefficient	1227.94	2364.18	192.53
	t-Stat	20.47	27.87	
	Signifi.	***	***	
Price	Coefficient	17.35	0	0
	t-Stat	2975.13	0	
	Signifi.	***	NS	
Profit	Coefficient	9940.99	7772.21	78.18
	t-Stat	7.42	4.1	
	Signifi.	***	***	
Note: *** = significant at 99 percent, ** = significant at 95 percent, * = significant at 90 percent, NS = not significant				

Even though Bt appears to have a dominant effect, perhaps also pulling its other inputs to boost the profitability, the performance can be considered a function of other inputs and factors as well. The model below relates the performance dependent variables to various factors including Bt, pesticide, seed, fertilizer, irrigation and state of location. These results would be affected to some extent by the multicollinearity across the explanatory variables. The results indicate that Bt is still statistically highly significant as a determinant of the yield, value of output and profitability. The impact on yield is estimated to be about 22 percent and the impact on profitability about 35 percent. Profit is negatively related to pesticide cost and positively related to seed cost and irrigation. The adverse relationship with fertilizer cost is perhaps a result of multicollinearity, whereas profits are significantly higher in Maharashtra as compared to Gujarat, there is no statistically significant difference in the profitability between Gujarat and Andhra Pradesh.

Table 21: Regression Results: Impact of Bt Cotton and Other Determinants									
		Independent Variables (N=515)							
Dependent Variable		Constant	Bt	Pesticide Cost	Seed Cost	Fertilizer Cost	Irrigation Status	Maha Dummy	AP Dummy
Yield	Coefficient	1912.78	428.03	0.0318	0.1469	-0.0819	475.07	-333.41	-37.70
	t-stat	16.36	3.78	2.27	3.44	-4.43	6.22	-2.94	-0.3
	Signifi.	***	***	**	***	***	***	**	NS
Value of Output	Coefficient	35854	7568.29	0.6136	3.3843	-1.2864	8440.21	-2875.29	-6810.50
	t-stat	15.08	3.28	2.16	3.9	-3.42	5.43	-1.25	-2.67
	Signifi.	***	***	**	***	***	***	NS	***
Total Cost	Coefficient	15637	392.30	1.2683	1.6172	1.2548	1117.76	-9105.81	-6689.49
	t-stat	20.7	0.54	14.03	5.86	10.49	2.26	-12.43	-8.25
	Signifi.	***	NS	***	***	***	**	***	***
Profit	Coefficient	20217	7175.99	-0.6547	1.7671	-2.5412	7322.45	6230.52	-121.014
	t-stat	9.85	3.61	-2.67	2.36	-7.82	5.46	3.13	-0.05
	Signifi.	***	***	***	**	***	***	***	NS
Note: *** = significant at 99 percent, ** = significant at 95 percent, * = significant at 90 percent, NS = not significant									

PERCEIVED BENEFITS AND THE FUTURE

The Table 22 below summarizes the results on the subjective assessment of Bt versus Non-Bt cotton by Bt cotton growers. The results indicate that by and large the farmers find no difference in the availability of seeds, fertilizer need, machine need, irrigation need or market preference. On the other hand, advantage or strong advantage is seen by a large majority of farmers in the pest incidence, pesticide need, cotton quality, staple length, yield and profitability. A large number report disadvantage in the seed cost. This may sum up the pros and cons of Bt cotton.

Table 22: Advantages or disadvantages of Bt cotton-G *vis-à-vis* non-Bt Cotton reported by Bt Cotton Growers: Percentage (Maharashtra, Andhra Pradesh and Tamil Nadu)

		Maharashtra, AP, Tamil Nadu				
		Strong Advantage	Advantage	No Difference	Disadvantage	Strong Disadvantage
1	Availability of seeds	0.0	4.4	62.1	32.7	0.7
2	Seed cost/price	0.0	2.5	6.9	26.7	30.6
3	Quality of available Seeds	2.0	51.5	44.9	1.6	0.0
4	Pest Incidence/problem	30.0	48.5	15.7	5.9	0.0
5	Pesticide need/cost	33.4	49.1	14.7	2.4	0.4
6	Fertilizer need/cost	1.0	14.3	72.9	11.8	0.0
7	Labour need/cost	0.8	20.5	73.5	5.2	0.0
8	Machine need/cost	0.8	2.7	95.7	0.4	0.4
9	Irrigation need/cost	2.0	13.5	72.1	12.4	0.0
10	Harvesting cost	1.5	28.5	58.1	11.5	0.4
11	Cotton quality	12.6	68.9	17.7	0.8	0.0
12	Market preference	3.8	24.3	69.5	2.0	0.4
13	Staple length	6.6	64.7	24.3	4.4	0.0
14	Fibre colour	12.9	56.7	27.7	2.4	0.4
15	Cotton price	5.2	10.6	81.8	2.4	0.0
16	Easy marketing	1.2	9.9	86.5	2.4	0.0
17	By-product output	0.8	3.2	96.0	0.0	0.0
18	Yield	17.9	78.5	3.1	0.4	0.0
19	Profit	18.9	66.9	12.6	1.5	0.0
20	Livestock feeding	0.8	3.6	95.6	0.0	0.0
21	Water saving	2.8	11.2	80.2	5.7	0.0
22	Suitable for early sowing	4.9	22.3	72.8	0.0	0.0
23	Suitable for late sowing	0.8	3.3	90.6	5.3	0.0

The Table 23 below examines the question of who recommended the growing of Bt cotton to the farmers. It is based on information available from the state of Maharashtra. The data indicates that in most cases the farmers were influenced by other farmers, who recommended Bt cotton to them. The extension workers did not play much of a role. In 31 percent of the cases, the farmers have indicated that the recommendation came from the seed companies or dealers.

The Table 24 below indicates that the benefits projected by the sales agents and dealers is primarily more profit. The other benefits projected are less pesticide spraying and comparatively more bolls. Thus the promotion done by the agents does not appear to be unreasonable.

Table 23: Bt cotton Farmer Response on Who Recommended the Growing of Bt cotton : Maharashtra	
Who recommended.	(Percentage)
1.Extension Worker	2.47
2. Fellow Farmer	50.62
3. Village Leader	7.41
4. Village Cooperative	7.41
5. Seed Company	20.99
6. Seed Dealer	11.11

Table 24: Advantages of Bt Seed as opposed to traditional Cotton Conveyed by Dealers/ Sales Agents: Maharashtra	
	Percent
1. More Profit	73.24
2. Less Pesticides Spraying	66.20
3. No Boll Shedding	15.49
4. Comparatively more Bolls	59.15

The Table 25 below indicates that in Maharashtra there was no government inspection of the cotton planted in the farmer's field. The farmers, as expected need to buy cotton seeds every year, and the seeds are easily available. 94 percent of the farmers indicate that they will continue with the cultivation of Bt cotton in the following year.

Table 25: Some Economic Characteristics of Bt Cotton: Maharashtra			
Question	Yes	No	No Opinion
Did any Government agency approach you for inspecting the cotton variety you have sown?	0	100	0
Do you need to buy Bt cotton seed every year?	100	0	0
Is Bt cotton seed easily available?	97.6	2.4	0
Do you face any problem in marketing of Bt cotton?	0	100	0
Will you continue with Bt cotton cultivation?	94.1	2.4	2.4

Since Bt cotton seed is expensive, it is important that the seeds are used judiciously to keep the seed cost low. The response from the farmers given in the Table 26 below indicates that this is indeed the case with a large number reducing the seed rate to 25 percent and another large number reducing it to between 25 and 50 percent.

Table 26: Percentage of Farmers Reporting Use of Lower Seed Rate: Maharashtra	
Percentage of Farmers Reporting Use of Lower Seed Rate in Bt	100
Less than 25%	57.65
Between 25 to 50 %	42.45

Table 27 below gives the responses on some other questions. The farmers indicate that the Bt cotton plants are not shorter or have smaller bolls or give lesser number of pickings. 82 percent indicate that Bt is more resistant than Non-Bt. With respect to the environment, the responses indicate that Bt cotton growing is not seen to be associated with more or less pest attack on other crops, and the farmers have not seen any adverse effect of Bt cotton on the environment. The Table 28 below indicates that even farmers in Tamil Nadu have not observed any adverse effects of Bt cotton on the environment.

Table 27: Some Physical Characteristics of Bt Cotton: Maharashtra			
Question	Yes	No	No Opinion/ Neither
2. Is Bt cotton plant shorter?	0	100	0
3. Does Bt cotton have smaller bolls?	0	100	0
4. Does Bt cotton give lesser number of cotton pickings?	0	96.5	3.5
7. In your opinion is Bt cotton is more pest resistant than non-Bt?	82.4	14.1	3.5
11. Do you feel that the pest/insect attack on other crop is higher or lower, when Bt Cotton is cultivated??	0	0	100
12. Have you observed any adverse effect on the environment due to Bt Cotton cultivation??	0	100	0

Table 28: Have You Observed any Adverse Impact of Bt cotton on the Environment?: Tamil Nadu		
Adverse Impact on Environment Observed	Percent reporting	
	Bt Growers	Non-Bt Growers
Yes	0	0
No	100	100

The Table 29 below indicates that the major suggestion given by the farmers to improve the benefits of Bt cotton technology is to reduce the cost of seeds. Some farmers in Maharashtra and all farmers in Tamil Nadu are requesting for more extension through field visits and field demonstrations. Some farmers in Maharashtra and all farmers in Tamil Nadu are concerned about spurious seeds and the need to improve the assurance of seed quality.

Table 29: Suggestion for improving the benefits of Bt Cotton technology:	
Maharashtra	
	Percent
Reduce Seed Cost	53.97
Seed Packages with Less Quantity seeds	14.29
Field Demonstration	33.33
Assurance of Seed Quality	6.35
Tamil Nadu	
Reduce the Price of Seed	100
Field Visit and Guidance by Extension Agencies	100
Traders should not sell spurious seeds	100

CONCLUSIONS

The paper presents preliminary results from a study of the economics and adoption of Bt cotton in India. Biotech crops, which made their appearance in the world about a decade ago, have gained substantial popularity and acceptance in many parts of the world. However, their introduction in India has been relatively late and they still have considerable ground to cover in the country. Cotton is an important commercial crop in India but has substantial problems particularly from extensive pest damage and poor yields. In light of this, Bt cotton offers a very promising solution to these serious problems.

Data from the survey, which covered the important cotton states of Gujarat, Maharashtra, Andhra Pradesh and Tamil Nadu indicates that Bt cotton offers good resistance to bollworms as well as several other pests. The incidence of these pests is reported to be considerably lower in Bt cotton versus Non-Bt cotton. The yields of Bt cotton are found to be higher and the yield increase statistically significant in all the states under both irrigated and rain-fed conditions. As a result, given the good market acceptance of the product, the value of output per hectare is higher in all the states and conditions. The question of higher cost of cultivation exists because of high seed cost and not commensurate reduction in pesticide cost. However, the profit is found to be higher in all the states to the estimated extent of about 80-90 percent on an average when the effect of the associated inputs are included. The returns are highest in Maharashtra followed by Gujarat and then Andhra Pradesh in value terms. Subjective assessment indicates that farmers find advantage in pest incidence, pesticide cost, cotton quality, yield and profit. Almost all farmers indicate that they plan to plant Bt cotton in the future. To increase the benefits from the technology, the farmers strongly urge reduction in the seed cost and greater field extension and demonstration work on the correct practices.

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