Is Bt Cotton Cultivation Economically Viable for Indian Farmers?

An Empirical Analysis

Though cotton has been cultivated predominantly in many parts of India, its productivity is one of the lowest in the world mainly due to attacks by pests/insects and low coverage of irrigation facility. Despite using pesticides, farmers are unable to control the bollworm, the key pest in cotton, that ravages up to 80 per cent of crop output. Bt cotton introduced in March 2002 for commercial cultivation in India is considered an important variety in protecting the crop from bollworm attack. However, not many credible studies are available focusing on the economic aspects of Bt cotton cultivation using properly designed sample survey data. In this paper, using data collected from 150 sample farmers from two districts in Maharashtra, an attempt has been made to study the economics of Bt cotton cultivation. This study provides an in-depth analysis of the impact of Bt cotton on pesticide use, costs of cultivation, productivity and profit.

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Cotton is one of the important cash crops of the country. It occupies a significant place in the agricultural and industrial (textile) economy of the country. Nearly 15 million farmers spread out in over 10 states are dependent on cotton cultivation for their livelihood [Sharma 1998]. At the end of 2002, the total area under cotton crop in the country was about 9.10 million hectares (mha), which accounts for about 6 per cent of net cropped area [GoI 2002; CACP 2004]. India, which is the third-largest producer of cotton in the world behind China and the US, accounts for 25 per cent of the world acreage but only 14 per cent of world production. Despite being one of the largest cotton growers in the world, cotton yield in India is one of the lowest in the world because of severe pest ravages and its predominant cultivation under rainfed conditions.

Though cotton crop is cultivated across different states in India, major cotton producing states are Maharashtra, Gujarat and Andhra Pradesh. While these three states together occupied about 65 per cent of India's total area in 2001-02, Maharashtra alone accounted for 34 per cent during the same period. Unlike other commercial crops, at the national level, almost 66 per cent of area under cotton was cultivated under rainfed condition as late as during 2000-01 [GoI 2002]. Farmers cultivating cotton crop have been encountering many problems in India, some of which are totally different from other crops. While predominant cultivation of cotton under rainfed condition increases the uncertainty in getting the expected yield, different kinds of pests attack significantly reduce the yield of crop. Controlling bollworms is a major as well as a persistent problem standing before the farmers throughout different regions in the country. Available estimates show that out of the total pesticides consumption of Rs 2,800 crore in Indian agriculture, about Rs 1,600 crore were spent on cotton alone, of which Rs 1,100 crore were spent only to control bollworms [Alagh 1988; Mayee et al 2002]. The indiscriminate application of pesticides partly due to spurious pesticides available in the market as well as proactive marketing strategies followed by pesticide companies that has further aggravated the situation [Deshpande 2002]. The indiscriminate use of pesticides not only increases the financial burden of the farmers and reduces the profit margins by increasing the cost of cultivation but also creates health hazards and environmental risks. In fact, due to drastic decline in yield mainly due to bollworms attack and increase in cost of cultivation, the cotton cultivation is increasingly becoming uneconomical, which may have in some instances lead to farmers' suicides [Deshpande 2002].

The Bt (stands for Bacillus Thuringiensis) cotton introduced recently for commercial cultivation considered to be an important variety, which can overcome the problems of bollworms in cotton [Mayee et al 2002]. Results from experimental station indicate that Bt cotton also increases the yield of crop significantly compared to hybrid cotton, besides reducing bollworms attack and cost of cultivation significantly [Mayee et al 2002]. Despite some controversies about its environmental problems, Bt cotton cultivation is steadily increasing all over the world including India. The world's total area of Bt cotton has increased from mere 3 mha in 1996 to 46.9 mha in 2002. Since Bt cotton is approved for commercial cultivation only in 2002 by the government of India, the total area under Bt cotton in India is not clearly known as of today [Iyengar and Lalitha 2002].

Though the Bt cotton has been allowed to cultivate since April 2002 in certain states in India, there are no credible studies focusing on the economic aspects of Bt cotton cultivation using field level data in India. Since it is a new variety of cotton and the cost of seed is substantially higher than the other varieties of cotton, it is essential to find out the answers to questions like: What are the characteristics of the farmers cultivating Bt cotton? What is the input use pattern of Bt and non-Bt cotton farmers? Does it reduce the cost of cultivation as claimed by the Bt cotton seed company? What is the yield gain from Bt cotton in comparison to non-Bt cotton? What is profit margin of Bt cotton when compared to non-Bt cotton? etc. Using field survey data collected

from two districts in Maharashtra, the present paper attempts to probe the above questions.

The paper has eight sections. Section I presents a detailed review of literature on Bt cotton cultivation and the controversies emanating from it, Section II presents the empirical setting of the paper, wherein a brief note on study area as well as the sampling design is presented. Agro-economic characteristics of the sample farmers are presented in Section III. Details of input use pattern as well as cost of cultivation of Bt and non-Bt crops are discussed respectively in Sections IV and V. An analysis about the productivity of Bt and non-Bt cotton is presented in Section VI. While the economics of Bt cotton crop is detailed in Section VII, pointers for policy are presented in Section VIII.

I
Controversies

Since the introduction of Bt cotton in India, lots of controversies have erupted about its impact on various parameters. It would be useful to understand the overall findings of the existing studies as well as the controversies revolving around the cultivation of Bt cotton before getting into field data. Farmers have started cultivating Bt cotton crop since April 2002 in India.[1] Within a short span of time, quite a few studies have looked into the impact of the Bt cotton crop on different parameters including its economics using data mostly from field trails and observations. Though information is available on various aspects of Bt cotton cultivation, we specifically look at the impact of Bt cotton on the use of pesticides, cost of cultivation and productivity of the crop.

As regards the impact of Bt cotton on pesticides use, studies carried out in Maharashtra and Andhra Pradesh show no reduction in the use of pesticides due to Bt cotton [Sahai and Rahman 2003; Shiva et al 1999]. But, contrary to the results of these studies, quite a few studies have found some reduction in the use of pesticides due to the adoption of Bt cotton [Mayee et al 2002; Sharma 2001; Pray et al 2001; Huang et al 2002; Ismael et al 2002]. The other issue associated with Bt cotton crop is whether it indeed reduces the cost of cultivation. Most of the studies in this regard show that the cost of cultivation required for cultivating Bt cotton is higher than that of non-Bt varieties [Shiva et al 1999; Pray et al 2001; Iyengar and Lalitha 2002; Yamaguchi and Harris 2003]. Since Bt cotton requires relatively more amount of yield increasing inputs, the cost of cultivation is found to be higher in all the studies that we reviewed.

Another issue associated with Bt cotton is whether it increases productivity over non-Bt cotton. Since the Bt cotton is expected to increase the yield of crop by reducing the bollworm attack, a number of studies have specifically attempted to find out its impact on yield. While the results of large number studies seem to indicate that the yield of Bt cotton is higher than that of the non-Bt cotton [Chaturvedi 2002; Pray et al 2001; Ismael et al 2002; Huang et al 2002; Dong et al 2004], some studies have found a reduction in the yield of Bt cotton or insignificant increase in yield of Bt cotton [Shiva et al 1999; Sahai 2002a; Sahai 2002b].

It is clear from the above that the impact of the Bt cotton on different parameters is not uniform. Apart from varying results from different studies, most of the studies one way or the other appear to have the following methodological deficiencies. First, though it is a known fact that variety of the crop determines its productivity to a considerable extent, most of the studies have not specified the varieties of the cotton while carrying out the study.

Second, the availability of irrigation is an important factor which determines the productivity of cotton. However, the studies that we reviewed have not specified whether the sample farmers are drawn from irrigated area or rainfed areas. Third, most of the existing studies were either carried out without following any sample design or with no specification of the method used for selecting sample farmers. In fact, a large number of studies we reviewed for this study appear like field notes. Therefore, keeping in view the above points, the present study makes an attempt to find out the impact of Bt cotton on different parameters using properly designed sample survey data collected from the Vidarbha region of Maharashtra. While bringing out the real economic impact of Bt cotton, the present study would also help to verify the claims and counterclaims made by the researchers and seed manufacturers about its superiority over non-Bt cotton.

II
Empirical Setting

Maharashtra, in western India, is an important state in cultivating cotton crops. According to the latest information (in TE 2001-02), Maharashtra cultivates about 3.15 million hectares of cotton, which accounts for nearly 36 per cent of India's total (8.78 million hectares) cotton area [GoI 2002]. Available information also suggests that the area under Bt cotton has been relatively larger in this state. In view of the predominant cultivation of cotton crop, Maharashtra became an obvious choice for studying the economics of Bt cotton. The study has been carried out mainly utilising field survey data collected from two districts of Vidarbha region in Maharashtra, which accounts for about 52 per cent of the total cotton area in the state in 2001-02. Available information also indicates that this genetically modified crop is cultivated relatively more in the Vidarbha region as well. Using the list of Bt cotton growers (kharif season, 2003) obtained from the commissionerate of agriculture, government of Maharashtra, Pune, two districts having relatively higher area under Bt cotton as well as non-Bt cotton have been selected for field survey. The selected two districts by this method are Buldhana and Yavatmal; two blocks from each district were selected using the same method followed for selecting districts. The four blocks selected from the two districts for the field survey are Jalgaon-Jamod and Sangrampur from Buldhana district and Ralegaon and Dharwa from Yavatmal district. Since the variety used for cultivating cotton plays a crucial role in determining the productivity of cotton, from each district, we have considered two important cotton varieties, one each from Bt cotton and non-Bt cotton, to study the impact of Bt cotton on productivity and other economic parameters. Accordingly, from Buldhana district, farmers cultivating MECH 162, which is an approved Bt cotton variety, have been selected to compare with those farmers cultivating a non-Bt cotton variety, namely, Bunny 145. Similarly, from Yavatmal district, those farmers cultivating MECH 184, an another approved Bt cotton variety, have been selected to compare with the farmers cultivating an another non-Bt variety, namely, Ankur 651.

A total sample of 150 farmers, 100 Bt cotton growing farmers and 50 non-Bt cotton growing farmers, have been selected from two districts for field survey. Sample farmers have been selected from each category of landholding size based on the landholding

distribution of the respective districts.[2] Further, our pilot survey as well as discussions with the officials having knowledge on Bt cotton indicates that most of the farmers one way or the other have availed irrigation facilities for cultivating Bt cotton crop.[3] Therefore, those farmers cultivating Bt cotton as well as non-Bt cotton using irrigation facility have only been selected for this study to avoid the impact of irrigation on productivity of crop and other parameters. Since only a few farmers in each village cultivate Bt cotton, the purposive sampling method has been followed to select the sample farmers cultivating Bt cotton. Farmers who cultivated non-Bt cotton nearest to the field of Bt cotton farmers have been selected purposively as non-Bt cotton sample farmers. This is done specifically to reduce differences in soil quality and other agro-economic factors between the two groups of farmers. Comparison has been made between Bt cotton and non-Bt cotton farmers with regard to different parameters to understand the benefits or otherwise of Bt cotton. The field level information on Bt and non-Bt cotton cultivation have been collected from the sample farmers who have cultivated cotton crop during kharif season 2003.

III
Characteristics

The theories as well as the empirical works on the adoption of new technological components in agriculture suggest that the socio-economic characteristics of the farmers such as community/ caste, farming experience, etc, play a critical role in adopting any new technology in agriculture [Lockheed et al 1980; Azhar 1991]. Since Bt cotton is a new technology introduced only recently in Indian agriculture, we have studied the socio-economic characteristics of Bt and non-Bt cotton growers. It is clear from Table 1 that the personal characteristics of both Bt and non-Bt farmers are by and large are same, except the level of education. The average education of the households cultivation of Bt cotton is 9.08 years whereas the same comes to only 6.85 years for non-Bt counterpart.[4]

Agro-economic characteristics such as land quality, landholding size, irrigation availability including source of irrigation, etc, generally determine the adoption of any modern technology in agriculture. Since the seed price of Bt cotton is very high as compared to non-Bt cotton seed, it was expected that the average landholding size of the Bt cotton growers must be higher than the non-Bt counterpart. However, this has not turned out to be true in our survey. Since Bt cotton variety is scale-neutral, the marginal and small farmers with some source of supplementary irrigation could adopt this new variety. Though the study selected only those farmers who cultivated the Bt and non-Bt varieties of cotton under irrigation, we could observe considerable differences in the per cent of irrigated area between the two groups of farmers. The share of irrigated area to gross cropped area (GCA) comes to 64.82 per cent for Bt cotton growers, whereas the same comes to only 53.07 per cent for non-Bt cotton growers. The main source of irrigation used by both groups of sample farmers in the two districts is groundwater, accounting for over 78 per cent among the farmers. Since the seed price of the Bt cotton variety is substantially higher (Rs 1,450-1,600 per acre) than that of the conventional hybrid variety (Rs 325-450 per acre), farmers do not want to take risks in cultivating Bt variety under rainfed conditions, where output is not assured. The substantially higher coverage of irrigation observed with the sample farmers suggests that the early adopters of Bt cotton are mainly irrigated farmers.

The cropping pattern of the sample farmers shows only a marginal difference between Bt and non-Bt cotton growers. Cotton is the main crop accounting for over 50 per cent of the gross cropped area in both the groups of farmers. However, in both districts, the non-Bt cotton farmers have allocated relatively higher share of their cropped area (about 57 to 65 per cent) to cotton crop as compared to Bt cotton growers (about 49 to 55 per cent). Since both the districts are traditionally cotton-growing areas, the sample farmers have allocated a major share of the cropped area to it. The share of area under selected Bt (MECH 162 and MECH 184) and non-Bt (Bunny 145 and Ankur 651) cotton to the total cotton area account for only about 47 per cent of the total Bt cotton area in the two selected districts. This suggests that the households cultivating Bt cotton allocate more than 50 per cent of their cotton area still to non-Bt cotton varieties.

IV
Input Use Patterns

One of the objectives of the study is to find out whether or not any difference exists in input use patterns between Bt and non-Bt cotton growers. This is done specifically for two reasons. First, the Bt cotton is not only a new crop but also a cost-intensive crop as compared to conventional hybrid variety. Second, it is claimed by the seed company that Bt cotton reduces pest attacks (especially the bollworm) and therefore, it reduces the use of pesticides substantially. Table 2 depicts that except seeds, pesticides and bullock labour, all other inputs used by Bt cotton cultivators are considerably higher than that of non-Bt cotton cultivators. Bt cotton farmers have used substantially higher amount of yield-increasing inputs such as fertilisers and farm yard manure than their non-Bt counterpart group in both the districts. For instance, while the average use of NPK is 306.7 kg/ha among Bt cotton growers, the same is only about 219 kg/ha among

Table 1: Characteristics of Bt and Non-Bt Sample Households

Characteristics	Buldhana		Yavatmal		Two Districts	
	Bt (MECH 162)	Non-Bt (Bunny 145)	Bt (MECH 184)	Non-Bt (Ankur 651)	Bt	Non-Bt
1 No of households	50	25	50	25	100	50
2 Average size of family	5.4	5.2	4.9	5.4	5.1	5.3
3 Average farming experience (years)	17.26	15.81	17.69	19.12	17.47	17.47
4 Average education (years)	7.51	7.06	10.65	6.65	9.08	6.85
5 Per cent of household having agriculture as main occupation	94.0	100.0	80.0	84.0	87.0	92.0
6 Average land size (ha)	2.66	2.85	3.30	2.70	2.98	2.78
7 Per cent of irrigated area	68.35	66.12	61.64	37.17	64.82	53.07
8 Cropping pattern (per cent to GCA)						
Foodgrains	25.83	19.30	24.47	26.29	24.17	22.45
Oilseeds	8.42	6.18	16.90	11.80	12.88	8.71
Cotton	55.09	65.31	49.55	57.64	52.18	61.85
Others	12.66	9.21	9.08	4.26	10.78	6.98
9 Cropping intensity (per cent)	130.51	125.46	120.41	110.70	125.00	118.35

Source: Field survey data.

non-Bt cotton growers, indicating a difference of over 40 per cent. Similarly, the difference in the use of FYM between Bt and non-Bt cotton growers comes to nearly 80 per cent. The same trend is observed in both districts selected for the study. Since most of the Bt cotton cultivators are progressive farmers, the use of yield-increasing inputs is found to be higher among them.

All the farmers belonging to both Bt and non-Bt groups have followed the recommended rate of seed input. While the seed rate used by the Bt cotton cultivators varies from 1,128 gram/ha to 1,224 gram/ha in the selected two districts, the same used by the non-Bt cultivators ranges from about 1,112 gram/ha to 1,798 gram/ha. The Bt cotton cultivators have used 450 gram of seed per acre (excluding refugee seed of 120 gram) as prescribed by the seed companies. Similarly, the non-Bt hybrid cultivators have also used recommended seed rate of 450 gram per acre. The variation in seed use in both varieties of cotton occurs mainly because holding size of the cotton cultivators may be fractional in nature and different spacing arrangements followed by the cultivators. However, quite a few farmers who are mainly marginal and small have not planted the refugee variety of cotton, partly because of limited land resources and partly due to awareness problem.

Bt cotton farmers are very much satisfied with the seed germination process. On an average, it comes to over 90 per cent in both districts, which is much higher than the guarantee given by the seed company.[5] The germination per cent of non-Bt seed varieties is also found to be equally good. Since both groups of farmers have cultivated cotton under irrigated conditions where moisture stress is very less, the germination per cent of seed is found to be higher. However, one needs to find out whether or not the guarantee given by the seed company about seed germination is correct under rainfed conditions as cotton crop is cultivated predominantly under rainfed conditions in India.[6]

Another input, which is considered very important in cotton cultivation, is pesticides. It is argued that Bt cotton requires less amount of pesticides as compared to non-Bt cotton varieties. However, this is not completely borne out by survey data (Table 3). Farmers cultivating Bt cotton variety of MECH 184 in Yavatmal district have used lesser amounts of pesticide spray (2.65) as compared to the hybrid variety of Ankur 651 (4.74). But, this is not true in the case of Buldhana district, where farmers have cultivated Bt cotton variety of MECH 162. The amount of spray used by the farmers cultivating MECH 162 is higher (5.79 times) than those farmers cultivating non-Bt cotton variety of Bunny 145 (4.41). Similarly, the total quantity of pesticides used by Bt cotton farmers is also found to be higher as compared to non-Bt cotton cultivators, though there are differences between the two varieties of Bt cotton. As a result of higher use (quantity) of pesticides, the expenditure incurred on account of pesticides by the Bt cultivators is also higher in both districts. The cultivators of Bt variety MECH 162 have incurred an expenditure about 8 per cent higher than the non-Bt (Bunny 145) cultivators in Buldhana district. Similarly, in Yavatmal district, the Bt cotton (MECH 184) farmers have spent nearly 17 per cent over the expenditure incurred by the non-Bt cotton cultivators (Ankur 651). Among the two varieties of Bt cotton, the consumption of pesticides is found to be higher in MECH 162 as compared to MECH 184. According to the farmers, MECH 162 variety is more susceptible to pests and diseases as compared to MECH 184.

One may be interested to know as to why is the use of pesticides or spray of pesticides higher in Bt cotton? We have come across several reasons for this while carrying out the survey in the study

Table 2: Input Use Pattern of Bt and Non-Bt Cotton Cultivators

(In ha)

Inputs	Buldhana			Yavatmal			Two Districts		
	Bt (MECH 162)	Non-Bt (Bunny 145)	Per Cent ONBt	Bt (MECH 184)	Non-Bt (Ankur 651)	Per Cent ONBt	Bt	Non-Bt	Per Cent ONBt
1 Manual labours (days)	119.85	108.05	10.92	101.79	89.95	13.17	108.83	99.93	8.91
2 Bullock labours (pairs)	15.25	17.12	-10.89	17.54	16.77	4.59	16.65	16.96	-1.85
3 Tractor (hrs)	7.07	5.52	28.12	3.47	1.27	173.61	4.88	3.61	34.96
4 Seed (gms)	1141.80	1112.29	2.65	1166.80	1798.18	-35.11	1157.10	1419.98	-18.51
5 Fertilisers (kg)									
N	134.33	121.82	10.27	140.13	106.77	31.25	137.87	115.07	19.81
P	132.09	119.70	10.35	105.82	48.18	119.64	116.06	87.62	32.46
K	74.33	29.66	150.59	39.08	0.00	-	52.82	16.36	222.97
Total NPK	340.75	271.19	25.65	285.03	154.95	83.95	306.75	219.04	40.04
6 FYM (cart load)	17.46	8.35	109.20	13.84	8.65	60.10	15.25	8.48	79.84
7 Pesticides (litre)	4.88	4.62	5.66	2.92	2.99	-2.66	3.68	3.89	-5.40
8 Irrigation (nos)	4.60	1.69	172.19	2.23	1.25	78.40	3.15	1.50	110.00

Note: Per cent ONBt – per cent over non-Bt cotton.
Source: Field survey data.

Table 3: Amount of Spray and Quantity of Pesticides Used in Bt and Non-Bt Cotton

(ha)

Particulars	Buldhana			Yavatmal			Two Districts		
	Bt (MECH 162)	Non-Bt (Bunny 145)	Per Cent ONBt	Bt (MECH 184)	Non-Bt (Ankur 651)	Per Cent ONBt	Bt	Non-Bt	Per Cent ONBt
1 Number of spray	5.79	4.41	31.41	2.65	4.74	-44.08	3.87	4.56	-14.96
2 Quantity per spray (milli litre)	842.78	1048.08	-19.59	1100.00	631.87	74.09	950.15	853.85	11.28
3 Quantity of pesticides used (litre)	4.88	4.62	5.67	2.92	2.99	-2.66	3.68	3.89	-5.37
4 Cost of pesticides (Rs)	2861	2639	8.41	1962	1680	16.77	2313	2209	4.69

Note and Source: Same as in Table 2.

area. First, a majority of the farmers is still not able to distinguish between the two varieties of cotton. The fear of bollworm attack is commonly seen among farmers and therefore, they continue to spray almost the same quantity of pesticides even for Bt cotton varieties. Second, the cotton crop is susceptible to many pests/diseases, besides bollworm attack. Though Bt cotton can withstand bollworm attack, it is not free from other sucking pests that are commonly seen in the early and middle stages of the crop. Therefore, farmers cultivating Bt variety are forced to adopt recommended doses of pesticides. Third, since Bt cotton farmers have already spent considerable amount of expenditure on seed and other inputs, they do not want to take any risks by not applying required levels of pesticides. Fourth, most farmers still adopt pesticides based on their own or co-farmers' experience and therefore, the use of pesticides is found to be higher among the Bt cotton farmers. Though the use of quantum of pesticides is higher in Bt cotton varieties (especially in MECH 162), one cannot simply say that it does not reduce pesticide consumption. This is because of the fact that the quality of pesticides including their possible effectiveness, used by the farmers is not the same. The real impact of the Bt cotton on the consumption of pesticides can only be understood, if the quality of the pesticides used by the farmers is also taken for the analysis.[7]

V
Cost of Cultivation

The views of existing studies on the impact of Bt cotton on cost of cultivation are not the same in India. Some argue that Bt cotton reduces costs of cultivation especially with regard to pesticides, while others do not agree with this (see, Section II). Detailed analysis has been made on costs of cultivation by comparing Bt cotton with non-Bt cotton. Results presented in Table 4 clearly shows that the costs of cultivation of Bt cotton is substantially higher than that of non-Bt cotton in both the districts.[8] The average costs of cultivation of the two districts comes to Rs 26,067/ha for Bt cotton and Rs 19,344/ha for non-Bt cotton, a difference of about 34 per cent over non-Bt cotton. While Bt cotton farmers have spent about 29 per cent over than the non-Bt cotton farmers in Buldhana district, the same difference comes to as much as 49 per cent per hectare in Yavatmal. There are several reasons for the higher costs of cultivation among the Bt cotton growers. First, the seed cost of Bt cotton varies from Rs 3,787 to Rs 4,062/ha, which is much higher than the seed cost of non-Bt cotton varieties (varies from Rs 1,027 to Rs 1,396/ha). Second, the expenditure incurred on fertilisers and FYM is substantially higher among Bt cotton growers – about 58 per cent higher than non-Bt cotton cultivators. Third, due to higher productivity of Bt cotton, the cost incurred on harvesting is also substantially higher than that for non-Bt cotton. Fourth, the cost of irrigation is also found to be much higher among Bt cotton growers. Apart from wide variation in the cost spent on yield-increasing inputs, Bt cotton farmers have also incurred about 42 per cent higher expenditure on transport and marketing over non-Bt cotton growers, mainly because of higher productivity.

VI
Productivity Issues

One of the important claims made by the supporters of transgenic crops is that it can increase productivity substantially as compared to the conventional hybrid/HYV varieties. Our survey in a way supports this claim. Productivity of both varieties of Bt cotton

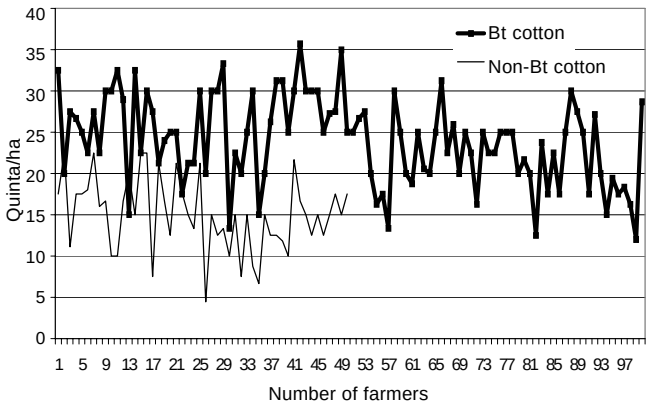
Table 4: Operation-wise Cost of Cultivation in Bt and Non-Bt Cotton

(in Rs/ha)

Particulars	Buldhana			Yavatmal			Two Districts		
	Bt (MECH 162)	Non-Bt (Bunny 145)	Per Cent ONBt	Bt (MECH 184)	Non-Bt (Ankur 651)	Per Cent ONBt	Bt	Non-Bt	Per Cent ONBt
1 Ploughing and preparation	1512	1693	-10.69	1661	1750	-5.06	1603	1719	-6.72
	(5.46)	(7.90)		(6.64)	(10.44)		(6.15)	(8.89)	
2 Harrowing	1014	1217	-16.67	1215	1309	-7.20	1136	1258	-9.67
	(3.66)	(5.67)		(4.85)	(7.81)		(4.36)	(6.50)	
3 Seed	3787	1027	268.61	4062	1396	190.93	3955	1193	231.55
	(13.67)	(4.79)		(16.23)	(8.33)		(15.17)	(6.17)	
4 Sowing	920	1131	-18.67	846	888	-4.69	875	1022	-14.40
	(3.32)	(5.28)		(3.38)	(5.29)		(3.36)	(5.28)	
5 Fertilisers	2467	1913	28.94	2163	1188	82.12	2281	1588	43.70
	(8.90)	(8.92)		(8.64)	(7.09)		(8.75)	(8.21)	
6 FYM	3139	1683	86.57	3088	1967	56.97	3108	1810	71.69
	(11.33)	(7.85)		(12.34)	(11.74)		(11.92)	(9.36)	
7 Pesticides	2861	2639	8.41	1962	1680	16.77	2313	2209	4.69
	(10.33)	(12.31)		(7.84)	(10.03)		(8.87)	(11.42)	
8 Weeding and interculture	2236	2467	-9.35	2170	2064	5.11	2196	2286	-3.96
	(8.07)	(11.50)		(8.67)	(12.32)		(8.42)	(11.82)	
9 Irrigation	1906	1624	17.37	1655	797	107.67	1753	1253	39.89
	(6.88)	(7.57)		(6.61)	(4.75)		(6.72)	(6.48)	
10 Harvesting (picking)	5687	4367	30.21	4332	2682	61.51	4860	3611	34.57
	(20.53)	(20.37)		(17.31)	(16.00)		(6.72)	(18.67)	
11 Transport and marketing	1790	1292	38.56	1548	985	57.11	1642	1154	42.27
	(6.46)	(6.02)		(6.19)	(5.88)		(18.64)	(5.97)	
12 Others	380	391	-2.72	321	55	486.57	344	240	43.24
	(1.37)	(1.82)		(1.28)	(0.33)		(6.30)	(1.24)	
Total	27700	21445	29.17	25024	16762	49.29	26067	19344	34.75
	(100.0)	(100.0)		(100.0)	(100.0)		(100.0)	(100.0)	

Notes: Figures in brackets are per cent to total; per cent ONBt – per cent over non-Bt cotton.
Source: Field survey data.

Figure : Farm-wise Variation in Bt and Non-Bt Cotton



is significantly higher than that of non-Bt cotton varieties (Table 5). The average productivity of two districts comes to 24 quintals/ha for Bt cotton, but the same is only about 15.77 quintals/ha for non-Bt cotton, indicating a difference of about 52 per cent. A similar trend is noticed in both Buldhana and Yavatmal districts. While the productivity difference comes to about 52 per cent in Buldhana, the same comes to about 65 per cent in Yavatmal district, where MECH 184 is compared with non-Bt variety of Ankur 651. There are quite a few reasons for the higher productivity in Bt cotton varieties. First, the bollworm attack was found to be very low in both varieties as compared to non-Bt varieties and thus, level of crop damage was less in Bt cotton. Despite applying higher quantity of pesticides in non-Bt varieties, many farmers had to face large crop damages due to bollworm attack. Second, though the size of the boll is relatively smaller in Bt cotton, the number of bolls on each plant was reported to be higher. Third, yield-increasing inputs used by Bt cotton growers are also found to be higher for both varieties as compared to non-Bt cotton growers.

Though Bt cotton has a higher productivity as compared to non-Bt varieties, we could find considerable variations between the two varieties selected for the analysis. The variety, MECH 162, has performed much better in terms of productivity (27.19 quintals/ha) as compared to MECH 184 (21.96 quintal/ha). There could be three reasons for this. First, farmers cultivating MECH 162 have used higher amounts of yield increasing inputs as compared to those cultivating MECH 184. Second, quite a few farmers have used sprinkler irrigation for the MECH 162 variety, which may have had an impact on productivity by reducing moisture stress.[9] Third, the land quality of the study area in Buldhana district is reported to be relatively better than that of Yavatmal district.

Apart from increasing productivity, Bt cotton also reduces the inter-farm variation in productivity as argued by supporters of transgenic crops. The results of our study reported in Table 5 shows that the variation in productivity across farms is less in Bt cotton as compared to the non-Bt cotton (see the figure). The coefficient of variation (CV) of productivity comes to 22.40 per cent for Bt cotton, whereas the same is almost 30 per cent in the case of non-Bt cotton. Similarly, the range in productivity of cotton varies from 12 to 35.7 quintals/ha in Bt cotton, whereas it varies from 4.4 to 22.5 quintals/ha for non-Bt varieties. The lowest yield achieved by non-Bt farmers is 4.40 quintals/ha in Yavatmal, which is much lower than the lowest yield noted in Bt cotton (12 quintals/ha). In fact, many non-Bt cotton farmers have led to a yield of less than 10 quintals/ha, which is not at all seen in Bt cotton crop.

Besides studying productivity, an attempt has also been made to find out whether or not the argument of uniform maturity for Bt cotton is correct by studying the number of pickings used for harvesting cotton. Data presented in Table 6 shows absolutely no variation in the picking-wise harvesting of cotton between Bt and non-Bt cotton varieties. About 80 per cent of cotton is harvested at the end of fourth picking in both varieties of cotton. However, many farmers have reported that the purity of cotton, particularly harvested after the fourth picking is much better in Bt cotton as compared to the non-Bt cotton variety.

After having analysed productivity differences between Bt and non-Bt cotton varieties, we have tried to find out the relative contribution of various factors to productivity of cotton using regression analysis. Specifically, we have tried to find out the impact of Bt variety on productivity of cotton. With the following

Table 5: Productivity of Bt and Non-Bt Cotton

Districts	Variety	Area (ha)	Productivity (Qtls/ha)	Range in Productivity (Qtls/ha)
Buldhana	Bt (MECH 162)	33.50	27.19 (20.10)	13.3 to 35.7
	Non-Bt (Bunny 145)	23.60	17.80 (25.20)	7.5 to 22.5
	Per cent ONBt	-	52.75	-
Yavatmal	Bt (MECH 184)	52.45	21.96 (21.30)	12.0 to 31.3
	Non-Bt (Ankur 651)	19.20	13.28 (28.80)	4.4 to 21.7
	Per cent ONBt	-	65.38	-
Two districts	Bt	85.95	24.00 (22.40)	12.0 to 35.7
	Non-Bt	42.80	15.77 (29.70)	4.4 to 22.5
	Per cent ONBt	-	52.19	-

Notes: Figures in brackets are coefficient of variation; Per cent ONBt – Per cent over non-Bt cotton.
Source: Field survey data.

Table 6: 'Picking' Related Productivity of Bt and Non-Bt Cotton
(Quintals/ha)

Picking	Buldhana		Yavatmal		Two Districts	
	Bt (MECH 162)	Non-Bt (Bunny 145)	Bt (MECH 184)	Non-Bt (Ankur 651)	Bt	Non-Bt
First	3.46 (12.73)	2.14 (12.02)	3.06 (13.93)	2.45 (18.43)	3.22 (13.40)	2.28 (14.44)
Second	4.97 (18.28)	3.62 (20.36)	4.96 (22.57)	3.54 (26.67)	4.96 (20.67)	3.59 (22.74)
Third	7.87 (28.92)	4.66 (26.19)	6.55 (29.82)	3.57 (26.86)	7.06 (29.42)	4.17 (26.44)
Fourth	5.46 (20.06)	3.86 (21.67)	3.46 (15.76)	1.90 (14.31)	4.24 (17.66)	2.98 (18.89)
Fifth	2.88 (10.59)	2.22 (12.50)	2.56 (11.68)	1.20 (9.02)	2.69 (11.20)	1.76 (11.19)
Sixth	2.13 (7.82)	1.29 (7.26)	1.37 (6.25)	0.63 (4.71)	1.67 (6.94)	0.99 (6.30)
Seventh	0.36 (1.32)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.14 (0.58)	0.00 (0.00)
Eighth	0.07 (0.27)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.03 (0.12)	0.00 (0.00)
Total productivity	27.19 (100.0)	17.80 (100.0)	21.96 (100.0)	13.28 (100.0)	24.00 (100.0)	15.77 (100.0)

Note: Figures in brackets are percentages to productivity.
Source: Field survey data.

linear regression model, we aim to find out the contribution of each factor on productivity:

$$Yield = a+b_1EDU+b_2EXP+b_3LHS+b_4FIE+b_5FER +b_6FYM+b_7PES+b_8IRR+b_9VOD \quad ...(1)$$

where,

Yield – Productivity of cotton (quintal/ha)
EDU – Average education of the farmers involved in agriculture (in years)
EXP – Average experience of the farmers involved in agriculture (in years)
LHS – Landholding size (ha)
FIE – Farm improvement expenditures (Rs/ha)
FER – Expenditures on fertilisers (Rs/ha)
FYM – Expenditures on farm yard manure (Rs/ha)
PES – Expenditures on pesticides (Rs/ha)
IRR – Expenditures on irrigation (Rs/ha)
VOD – Variety dummy (1 for Bt cotton, 0 for non-Bt cotton)

Needless to mention, all the nine variables used in the equation (1) above are expected to contribute to the productivity of cotton one way or the other. Since the main aim of this analysis is to find out the impact of seed variety (Bt or non-Bt) on productivity cotton, variety dummy is used to differentiate Bt farmers from non-Bt farmers. Human resource variables such as education (EDU) and experience (EXP) are essential for adopting any new technological components and therefore, these two variables are used in our model. Inputs such as fertilisers, FYM, pesticides, irrigation, farm improvement expenditures (FIE)[10] are needed for any crop to increase the productivity and therefore, these variables are used in the model. Size of landholding (LHS), which is proved to be an important factor in determining the productivity of any crop, is used to reflect the resource position of the farmers.

The results of regression presented in Table 7 suggest that the variety dummy along with yield increasing inputs appear to have significantly contributed to the productivity of the cotton crop. Among the various factors, the variety dummy is turned out to be the most significant factor (highest coefficient value) in increasing the productivity of cotton. This is not surprising because most Bt cotton cultivators have secured a substantially higher productivity than that of their non-Bt counterparts. Followed by the variety dummy, yield-increasing inputs such as fertilisers, farm yard manure, irrigation and pesticides have also contributed significantly to productivity increase. As mentioned earlier, since the use of fertilisers, FYM, pesticides and irrigation is relatively higher with Bt cotton farmers, all these factors might have contributed in enhancing productivity of cotton. The insignificant coefficient of landholding size (LHS) of farmers suggests that there is no relationship between farm size and productivity of cotton in our study.

Table 7: Factors Contribution to Productivity of Cotton: Regression Results

Variables	Coefficients	't' value
1 Variety dummy (1=Bt and 0= Non-Bt)	6.1878	6.802 [a]
2 Education (years)	-0.0824	-0.747 [NS]
3 Experience (years)	-0.0148	-0.263 [NS]
4 Fertilisers (Rs)	0.0024	4.554 [a]
5 Farm improvement expenditures (Rs)	0.0003	0.934 [NS]
6 Farm yard manure (Rs)	0.0004	2.509 [b]
7 Landholding size (ha)	-0.0436	-0.300 [NS]
8 Irrigation (Rs)	0.0009	2.167 [b]
9 Pesticides (Rs)	0.0009	2.489 [b]
Constant	6.894	3.054 [a]
R^2	0.606	-
Adjusted R^2	0.580	-
F value	23.896 [a]	-
D-W value	1.98	-
N	150	-

Notes: a and b are significant at 1 and 5 per cent respectively; NS - not significant.
Source: Computed from field survey data.

VII
Economics of Bt and Non-Bt Cotton

Whether the cultivation of Bt cotton crop is economically viable for Indian farmers is an important issue that has been under discussion since the introduction of Bt cotton. The existing studies somehow are unable to provide a convincing answer on this issue. Since the present study is carried out using field survey data and that too covering relatively a large sample, it is expected to provide some answers as well as to resolve the controversies about the economics of Bt cotton cultivation. The economic viability of Bt cotton is studied in terms of profit per hectare. While the gross value of production per hectare is estimated by multiplying the productivity of cotton with the output price (per quintal) received by the farmers, the profit is calculated by deducting the cost of cultivation from the gross value of production.

Table 8 clearly shows that the profit realised from Bt cotton crop is substantially higher than that of the non-Bt cotton crop. While the average profit of the two districts comes to about Rs 31,880/ha for Bt cotton, it is only about Rs 17,790/ha for non-Bt cotton crop, indicating a difference of about Rs 14,090/ha. The profit realised by Bt cotton growers is nearly 80 per cent higher than that of non-Bt cotton cultivators. Though the same trend is observed in both the varieties of Bt cotton, the profit is found to be higher with MECH 162 variety (Rs 34,560/ha) as compared to MECH 184 (Rs 30,173/ha). This is mainly because of the relatively higher productivity realised by the farmers cultivating MECH 162. One might be interested to know as to how could the Bt cotton growers get such a higher profit than non-Bt cotton counterpart? Is the variation in profit due to higher output price received by Bt cotton growers? As mentioned earlier, in both Bt varieties of cotton, the sample farmers could harvest a substantially higher yield than non-Bt growers, which helped them secure a higher profit. Further, since sample farmers have received almost the same price for both Bt and non-Bt varieties

Table 8: Cost of Cultivation, Gross Value of Production and Profitability Comparisons

Particulars	Buldhana			Yavatmal			Two Districts		
	Bt (MECH 162)	Non-Bt (Bunny 145)	Per Cent ONBt	Bt (MECH 184)	Non-Bt (Ankur 651)	Per Cent ONBt	Bt	Non-Bt	Per Cent ONBt
1 Gross value of production (Rs/ha)	62260	40891	52.26	55197	32531	69.67	57950	37141	56.03
2 Gross cost of cultivation (Rs/ha)	27700	21445	29.17	25024	16762	49.29	26067	19344	34.75
3 Cost of production (Rs/quintal)	1019	1205	-15.47	1139	1262	-9.73	1086	1227	-11.46
4 Profit (Rs/ha)	34560	19446	77.72	30173	15769	91.34	31883	17797	79.15
5 GVP/GCC	2.25	1.91	–	2.21	1.94	–	2.22	1.92	–

Notes: GVP – gross value of production; GCC – gross cost of cultivation.
Source: Field survey data.

of cotton,[11] one can conclude that the higher profits from Bt cotton cultivation is mainly due to its higher productivity and not higher output price. The data on input and output patterns of Bt and non-Bt cotton cultivators presented in Table 8 also suggest that costs are utilised more efficiently as regards Bt cotton crop. The cost efficiency, which is measured in terms of costs required to produce one quintal of output in both the varieties of cotton shows that Bt crop requires only about Rs 1,086/quintal, as against the requirement of about Rs 1,226/quintal for non-Bt cotton crop. This higher cost efficiency observed in Bt cotton crop is possible mainly because of substantial increase in productivity of Bt cotton. Because of higher cost efficiency, the average output-input ratio[12] is also found to be higher for Bt cotton cultivators (2.22) as compared to non-Bt cotton cultivators (1.92). Overall, the analysis on income and expenditure suggests that the profit of Bt cotton cultivators is substantially higher than that of non-Bt cotton cultivators.

VIII
Pointers for Policy

The study shows that the costs of cultivation required for Bt cotton crop is substantially higher than that of non-Bt crop. Contrary to the claim made by the seed company, Bt cotton has not reduced the consumption of pesticides. In fact, farmers cultivating Bt cotton crop have had marginally higher expenditures on account of pesticides. However, productivity is found to be substantially higher in Bt cotton than that of non-Bt cotton varieties. The cost efficiency as well as profit per hectare is also found to be higher with those farmers cultivating Bt cotton crop. Although the results of the study clearly suggest that the productivity and profit from Bt cotton cultivation is substantially higher than the conventional hybrid cotton varieties, it is not completely free from problems. Information collected from the sample farmers to know their perceptions on various aspects of Bt cotton variety suggest the need to introduce various policy measures to sustain and improve the performance of Bt cotton cultivation in India. Some of the policy measures that need immediate attention are presented below.

First of all, the sample farmers have expressed that the seed cost of Bt cotton is very high as compared to non-Bt hybrid variety. The resource poor farmers (mainly marginal and small group) and the farmers practising rainfed cultivation are very much reluctant to cultivate this crop due to higher seed costs. Therefore, the seed cost of Bt cotton needs to be reduced. This can be done in two ways. First, as a short-term measure, direct subsidy could be extended for Bt cotton seed for a specific period of time. Second, as a long-term measure, the role of the public sector should be expanded in transgenic cotton seed production by activating research and development activities.

A large number of farmers have reported pests/diseases attack including that by bollworm particularly for MECH 162. As a result, farmers had applied a larger amount of spray as well as incurred a higher expenditure on account of pesticides. Though Bt cotton farmers have not faced any severe crop losses due to bollworm attack, the cost of cultivation has increased due to higher use of pesticides. Therefore, scientific trials at the farmers' field need to be carried out periodically to test whether or not Bt cotton varieties are free from bollworm attack. If crops are really found to be damaged due to bollworm attack, government authorities should help the affected farmers to get enough compensation from the seed companies. If required, government should also penalise the companies for making false propaganda about their seed varieties.

Quite a few farmers cultivating Bt cotton still continue to use the same quantity of pesticides as followed in the past partly because of poor awareness and partly due to fear of bollworm attack. In fact, farmers do not distinguish between Bt and non-Bt varieties of cotton at the time of spraying pesticides. Many Bt cotton growers fear that the bollworm can attack cotton crop any time and therefore, they tend to use more quantity of pesticides. Besides increasing cost of cultivation, the overuse of pesticides increases the social cost by polluting the environment as well. Therefore, the seed company, which involves in the production of Bt cotton seed should clearly advise the farmers at what circumstances they should spray pesticides.

Farmers, especially belonging to marginal and small farmers group have not planted refugee cotton around Bt cotton fields, as per the recommendation. This is partly because of limited land resources as well as inadequate information on the importance of refugee crop. The seed companies through quality extension network should explain to the farmers about the importance of planting refugee crop in protecting Bt cotton as well as the environment. Quite a few farmers have reported the problem of premature dropping of bolls from Bt cotton varieties. The extension officials are not able to provide correct measures to stop this premature dropping of bolls. Farmers argue that productivity of Bt cotton can be increased further, if suitable measures are suggested to control the dropping of premature bolls. Therefore, the seed company should make necessary arrangements to find out the reasons for premature dropping of bolls and suggest appropriate measures to the farmers.

Since Bt cotton is a new crop to the farmers in India, adequate efforts need to be taken by seed companies to propagate effective practices to be followed for cultivating Bt cotton. However, the information gathered from the field seems to indicate that the seed company has not taken any serious effort to disseminate this in the field. As indicated earlier, almost all the sample farmers have followed the package of practices suggested by the local 'krishi seva kendras', which are mostly suggested with profit motive. Therefore, it is suggested that the seed company should invest some portion of their profit exclusively for extension services to sustain the cultivation of Bt cotton. Finally, though the returns from Bt cotton crop is considerably higher than that of non-Bt cotton crop, one cannot firmly say that the same level of returns can be achieved throughout Maharashtra or India without any risk. The relative returns from Bt cotton crop is expected to be less in all those rainfed areas, where the adoption of various yield-increasing inputs/practices is generally less due to uncertainty in crop output. More comprehensive studies need to be carried out covering the crops cultivated under both irrigated and rainfed areas to find out whether Bt cotton can be cultivated without any risk under rainfed condition in countries like India, where over 65 per cent of area under cotton is still cultivated under rainfed condition. EPW

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Notes

[This paper forms part of the larger study on 'Economics of Bt Cotton Cultivation in Maharashtra' carried out when the first author was at the Gokhale Institute of Politics and Economics, Pune, India. The authors gratefully acknowledge the financial assistance provided by the NABARD, Mumbai,

for carrying out this study. The views expressed in this paper are authors own and should not be attributed to any affiliated organisation.]

1 The Genetic Engineering Approval Committee (GEAC) permitted Mahyco to commercially release three transgenic varieties of cotton, namely, MECH 12, MECH 162 and MECH 184 on March 26, 2002. This permission was given only for three-year period from April 2002 to March 2005 to cultivate only in states like Gujarat, Maharashtra, Madhya Pradesh and Andhra Pradesh [Iyengar and Lalitha 2002]. All the three varieties approved by GEAC are suited for central and south India. Another variety MECH 915, which is said to be suitable for the northern parts of India, could not be cleared by GEAC because its tests results were delayed [Singh 2002].

2 While selecting sample farmers, farmers have been grouped into five categories, namely, marginal (< 1.00 ha), small (1.00-2.00 ha), semi-medium (2.00-4.00 ha), medium (4.00-10.00 ha) and large (> 10.00 ha) as per the definition of the agricultural census of India.

3 A pilot survey has been carried out specifically to pre-test the interview schedule prepared for the study as per the terms and conditions of the study. This survey was done among five Bt cotton growers in two villages (Kapustalani and Takarkheda More) belonging to Anjangaon Surji taluka of Amaravati district in Maharashtra. Besides, a group discussion was also conducted among Bt cotton growers from the selected villages to get more information about the cultivation practices of Bt cotton at field level.

4 However, the survey reveals that many endogenous and exogenous factors (such as resource position of the farmers, irrigation availability, role of extension network and co-farmers, etc) have also played an important role in adopting Bt cotton variety, besides farmers' education. In fact, our survey shows that over 86 per cent of Bt cotton growers from both the districts could adopt this genetically modified variety mainly using information provided by the agricultural extension officials and krishi seva kendra.

5 The seed company assures a guarantee of at least 65 per cent of germination in Bt cotton seed. The other qualities of the seed guaranteed by the seed company are given below:

Particulars	MECH 184	MECH 162	MMECH 184/162 (Pouch)
Pure seeds (min) (per cent)	98	98	98
Germination (min) (per cent)	65	65	65
Other crop seeds (max)	10/kg	10/kg	10/kg
Weed seeds (max)	10/kg	10/kg	10/kg
Inner matter (max) (per cent)	2	2	2
Genetic purity (per cent)	90	90	90
Net weight (gm)	450	450	120

6 While the area under rainfed cotton accounts for over 65 per cent of India's total cotton area, the same comes to as high as 96 per cent in Maharashtra's total cotton area as of today.

7 It should be noted here that the real impact of Bt cotton on pesticides use cannot be judged only on the basis of quantity of use. Since the quality as well as vigour of each pesticide is different, one must analyse the quality of pesticides used by the farmers to get clear understanding about the impact of Bt cotton on pesticides consumption. Moreover, since Bt cottonseed can protect only from the bollworm attack, one should also preferably study the quantity of pesticides used at different stages of the crop. Unfortunately, we could not study these aspects due to data constraints.

8 As per the definition of the Commission for Agricultural Costs and Prices (CACP), our cost of cultivation refers to cost A2+FL. This includes all actual expenses in cash and kind incurred in production by owner, rent paid for leased in land as well as imputed value of family labour.

9 The positive impact of drip and sprinkler irrigation on productivity of different crops has been very well documented by studies in India [Narayanamoorthy 2004, 2004a]. Authors' own field observation in Jalgaon district and sources from drip manufactures (Jain Irrigation Systems, Jalgaon) indicate that the micro-irrigation technology enhances productivity of cotton appreciably.

10 FIE includes cost of ploughing and preparatory works, harrowing, sowing and weeding and interculture.

11 This is entirely different from the findings of some of the earlier studies, which have indicated that the quality of Bt cotton is graded as B and C, instead A and B in the local market and therefore, it fetched almost Rs 100 less per quintal as compared to non-Bt cotton varieties [Sahai and Rahman 2003].

12 This is the ratio of gross value of production (GVP) to gross cost of cultivation (GCC).

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