RESEARCH ARTICLE

Are there Benefits from the Cultivation of Bt Cotton? A Comment Based on Data from a Vidarbha Village

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Abstract: This note examines costs and returns from the cultivation of different types of cotton in a rainfed village in the Vidarbha region of Maharashtra, India. While the pros and cons of GM cotton are extensively debated, there are only a few empirical studies on the economic performance of Bt cotton, particularly under rainfed conditions. The results from a detailed survey of farm business incomes show that Bt cotton was a clear leader in terms of production and gross value of output when grown as a stand-alone crop. However, on the fields of small and marginal farmers, where cotton was usually intercropped with sorghum (or other cereals and pulses), the relative income advantage of Bt cotton declined. Further, expenditure on chemical pesticides was higher for Bt cotton than for other varieties of cotton. Variability in production was also higher for Bt cotton than for other types of cotton.

Keywords: GM, Bt cotton, costs of cultivation, incomes, village, Maharashtra, India.

INTRODUCTION

A recent review of the performance of Bt cotton in India, China, and South Africa argues that while "Bt cotton has had some beneficial impacts in the developing world," the benefits for poor small-holder farmers "are neither as simple, as uniform, as context-independent nor as sizable as they have frequently been depicted to be" (Glover 2010). This note examines the costs and returns from cultivation of different types of cotton in a rainfed village characterized by small-holder cultivation in the Vidarbha region of Maharashtra, and by doing so, contributes, we believe, to understanding the economic implications of growing Bt cotton in a specific institutional and socio-economic context.

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1 We are grateful to V. K. Ramachandran for clarifying our ideas and writing, to staff and associates of the Foundation for Agrarian Studies for assistance with data collection, entry, and processing, and to an anonymous referee for comments.

In the last few years, after the introduction and rapid spread of Bt cotton in India, there has been much debate on the pros and cons of the new technology.[2] There are several strands in the debate on Bt cotton technology, of which five important ones are, first, the transparency and functioning of the Genetic Engineering Approval Committee (GEAC) of the Government of India; secondly, the role of private multinational companies (Monsanto in particular) and their extraction of monopoly profits; thirdly, the nature of diffusion of the technology (including issues of seed quality and purity); fourthly, the safety, health implications, and environmental implications of the new technology; and, fifthly, the economic performance of Bt cotton in terms of costs and returns.

There are only a few detailed empirical research studies that examine the economic impact of the cultivation of Bt cotton in India. One of the first research papers on the impact of Bt cotton cultivation (Qaim 2003) argued that while "Bt cotton seeds are significantly more expensive than conventional hybrids, the productivity gains outweigh the higher seed costs and lead to large net benefits at the farm level" (*ibid.*, p. 2125). This research was based on field trials conducted before the official introduction of varieties of Bt cotton, and therefore does not reflect normal cultivation practices. The first survey of Bt cotton grown commercially was of 100 farming families in Andhra Pradesh and Maharashtra (Sahai and Rahman 2003), and the conclusions of the authors were that seed costs were four times higher for Bt than traditional varieties, and that the increase in seed costs was not compensated by yield increases or savings on pesticide use. Sahai and Rahman stated that the net profit was lower for Bt cotton than for non-Bt cotton.[3]

Gandhi and Namboodiri (2006) conducted a survey of 694 Bt and non-Bt cotton farmers in four States in 2004. Bennett *et al.* (2006) have analysed data from a survey conducted in 2002 and 2003 by the Maharashtra Hybrid Seed Company (MAHYCO), the Monsanto-owned company that was licensed to sell Bt cotton in India.[4] The MAHYCO survey did not collect data on labour costs and fertilizer costs. Qaim *et al.* (2006) is based on a survey done in 2003 of 341 cotton farmers in four States. Ramasundaram *et al.* (2007) collected data from Vidarbha in Maharashtra during 2002–04. Narayanamoorthy and Kalamkar (2006) also undertook a survey of irrigated cotton cultivators in Maharashtra. Loganathan *et al.* (2009) collected data from around 120 cultivators of Tamil Nadu in 2004–05. The most recent research is based on a survey of 623 cultivators in four districts of Andhra Pradesh in 2005 (Mahendra Dev and Rao 2007), with a follow up survey in 2007 (Rao and Mahendra Dev 2009).

2 These are cotton varieties with a gene from the bacterium Bacillus Thuringiensis, which provides resistance to bollworm pests. Area under Bt cotton in the country has grown very fast, from 1,00,000 hectares in 2003–04 to 76,00,000 hectares in 2008–09 (Rao and Dev 2009).

3 Shiva and Jafri (2004) have also questioned the benefits of Bt cotton, but the methodology of their study is not described.

4 The survey was conducted by A. C. Nielsen for MAHYCO.

Table 1 *Percentage changes with respect to yield, pesticides, and profits in Bt cotton vis-à-vis conventional hybrids in India* in per cent

Authors	Survey Year	Percentage increase in			
		Yield	Pesticide Costs	Profit	Cost
Naik *et al.* (2005)	2002–03	34	−41	69	47
AC Nielsen (2004)	2003–04	29	−60	78	NA
Narayanamoorthy and Kalamkar (2006)	2003–04	52	−5	79	34
Ramasundaram *et al.* (2007)	2002–04	25	−53	30	21
Gandhi and Namboodiri (2006)	2004–05	31	−24	88	7
Loganathan *et al.* (2009)	2004–05	65	−78	668	92
Mahendra Dev and Rao (2007) (with and without)	2004–05	32	−18	83	17
Rao and Mahendra Dev (2009) (after adoption)	2006–07	42	−56	251	−1

Source: Based on Rao and Mahendra Dev (2009), Table 1, and Ramasundaram *et al.* (2007), and Loganathan *et al.* (2009). We have excluded papers based on data from field trials.

These studies concur in respect of their major findings.[5]

First, they show conclusively that yields of Bt cotton are higher than yields of other varieties of cotton. The percentage increase in yield from sowing Bt cotton ranges from 29 to 65 per cent (Table 1). In the most recent study undertaken in Andhra Pradesh, the yield of Bt cotton is reported to be 30 per cent higher than that of non-Bt cotton (*ibid.*).[6]

Secondly, most studies show that returns or incomes to farmers were higher from the cultivation of Bt than from non-Bt cotton. Reviewing the earlier studies, Rao and Mahendra Dev (2009) note that the percentage increase in profits ranged between 69 to 88 per cent; in their most recent study, however, they estimate a 251 per cent increase in profit when a farmer shifts from other cotton to Bt cotton. A very big rise in profits was also observed in the study of Tamil Nadu (Table 1). There are, of course, variations across States. Gandhi and Namboodiri (2006) found that of the four States in their study, the returns were highest in Maharashtra. Qaim *et al.* (2006) noted that cultivators in Andhra Pradesh suffered losses, in contrast to those in Maharashtra, Karnataka and Tamil Nadu.

5 Similar results have been reported for China (Pray *et al.* 2001).
6 The dummy variable for Bt seed has a significant positive coefficient in their estimated production function.

Thirdly, in terms of the costs of specific inputs, all studies state that the expenditure on pesticides and insecticides is lower for Bt cotton than for other varieties of cotton, as is the actual quantity of chemicals applied. For example, according to Mahendra Dev and Rao (2007), costs of insecticides were lower by 18 per cent for Bt farmers than for non-Bt farmers. The amount of insecticide use was reduced by 50 per cent on Bt plots according to Qaim *et al.* (2006), and by 78 per cent according to Loganathan *et al.* (2009). A reduction in the use of chemicals, it is argued, can bring health and environmental benefits.

We have data from 186 cultivator households in one cotton-growing rainfed village of Maharashtra, surveyed in 2007 as part of a larger research project, Project on Agrarian Relations in India (PARI).[7] Our survey was a census of all households in the village. We collected detailed information on land ownership and operation; on crop cultivation; on costs and labour use by operation crop and season; and on asset ownership, indebtedness, and other household variables. In this paper, we use the data on costs and incomes to examine the returns from cotton cultivation. While data from one village can only be illustrative, we have the advantage of observations on all cultivators in a given location, and the advantage that the authors themselves were part of the survey team.

Two other village-level studies of the costs and profits from cotton cultivation have recently been conducted in Maharashtra: a study of Dongargon village (Ramakumar, Raut, and Kumar 2009) and one of Kanzara village (Subramanian and Qaim 2010). Both villages are in Akola district, which neighbours our study area, in Buldhana district. We discuss the findings from these two studies alongside our results in the third section of this paper.[8]

THE VILLAGE AND REGION

In 2007, we conducted a detailed census-type household survey in Warwat Khanderao, a village in the unirrigated cotton-growing tracts of the Vidarbha region of Maharashtra.

India is the third largest producer of cotton in the world, and the state of Maharashtra has the highest acreage under cotton in India. In 2006–07, 3.11 million hectares were

7 For further details on the Project on Agrarian Relations in India (PARI), see the website of the Foundation for Agrarian Studies (FAS) at www.agrarianstudies.org

8 Although Narayanamoorthy and Kalamkar (2006) selected Buldhana district as one of their sites, we have not used their results for comparison, as their sampling strategy resulted in their selecting only cultivators with irrigated land, despite cotton in Maharashtra being mainly an unirrigated crop. Further, Narayanamoorthy and Kalamkar state that they obtained a list of Bt cotton cultivators growing an approved variety from the local commissioner of agriculture, and then selected cultivators by land-holding size and with irrigation. The non-Bt cultivators were chosen purposively in the neighbourhood of the selected Bt cultivators. Without a full listing of cultivators in the selected blocks, it is not clear what this "sample" represents.

sown with cotton in Maharashtra, accounting for 34 per cent of all area under cotton in India. Cotton in India is grown mainly on small holdings. Most of the cotton in Maharashtra is cultivated on unirrigated or rainfed land (only 4.8 per cent of cropped area under cotton was irrigated) and yields in Maharashtra are lower than in other States. Maharashtra accounted for 20 per cent of national production in 2006–07. Cotton cultivation is typically on black soils.

Warwat Khanderao is in Sangrampur tehsil, Buldhana district, in the Vidarbha region of Maharashtra. The nearest town is Shegaon, which is 20 kilometres from the village. At our survey, there were 250 households with a population of 1,308 persons (at the Census of 2001, the population was 1,447) in the village. The literacy level of persons aged seven and above was 74 per cent, with a male literacy rate of 83 per cent and female literacy rate of 66 per cent. The major caste in the village was Kunbi (43 per cent of all households). Agriculture is the main occupation of residents, with 69 per cent of workers reported to be cultivators and another 15 per cent reported to be agricultural labourers (Census of India 2001). The remaining 16 per cent of workers included non-agricultural manual workers, and workers in business and services.

The pattern of ownership of land shows that 25 per cent of households did not operate any agricultural land (Table 2). Thirty per cent of operational holdings can be characterized as marginal farms (of less than 2.5 acres or 1 hectare) and another 23 per cent as small farms (2.5 to 5 acres). Thus, 53 per cent of farms were small holdings of up to 5 acres. The median extent of household land ownership was 3.5 acres (excluding the landless). The biggest landowner in the village owned 85 acres. Kunbis accounted for 43 per cent of the village households but owned 65 per cent of the land held by residents.

Table 2 *Distribution of operational land-holding, Warwat Khanderao village, 2007,* in acres and per cent

Size-class (acres)	No. of Households	% of Households	Area (acres)	% of area
0	62	24.8	0	0.0
>0≤1	15	6.0	14.25	1.3
>1–2.5	59	23.6	116.53	10.5
>2.5–5	57	22.8	217.88	19.7
>5–10	31	12.4	231.53	20.9
>10–20	19	7.6	260.80	23.5
20–85	7	2.8	267.00	24.1
All	250	100	1,107.99	100.0

Source: Survey data 2007.

Warwat Khanderao is a predominantly agricultural village. Of the 250 households surveyed, 183 obtained some income from crop production. The mean annual income from crop cultivation in 2006–07 was Rs 35,841 per household (the median was Rs 15,924) at current prices. Crop incomes accounted for 42 per cent of the incomes of resident households, making agriculture a major source of income. If we take the major landowning caste, Kunbis, we find that 83 per cent of households received incomes from crop production, and such incomes accounted for 49 per cent of their total household incomes.

CROPPING PATTERN

The major crop cultivated in 2007 was cotton, both Bt and non-Bt varieties. The area under cotton accounted for 77 per cent of gross cropped area (Table 3). Other crops grown included green gram, black gram, red gram, jowar, groundnut, sunflower, sesamum, maize, and wheat. Cotton was cultivated in the kharif season, that is, from June–July to October–November, and was intercropped mainly with green gram, black gram and red gram. A few cultivators raised wheat during the rabi season, that is, from November–December to February. Cultivation was mainly rainfed, although a few cultivators used borewells for irrigating the crop.

Table 3 *Gross cropped area under various crops, 2006–07, Warwat Khanderao village, by crop*, in acres

	Acreage	Share of GCA	Share of cotton area
Bt cotton intercropped with other crops	395	34.7	43.1
Premium non-Bt cotton intercropped with other crops	230	20.3	25.1
Bt cotton stand-alone	119	10.4	12.9
Local non-Bt cotton intercropped with other crops	107	9.4	11.6
Local non-Bt cotton stand-alone	42	3.7	4.5
Premium non-Bt cotton stand-alone	25	2.2	2.7
Sorghum (*Jowar*)	93	8.2	-
Pulses	47	4.1	-
Wheat	21	1.8	-
All crops*	1137	100.0	100.0

Note: * The column does not add up as area under minor crops is included in the total for all crops.
Source: Survey data 2007.

There are three features of cropping pattern and farming practices that we shall highlight here. First, several varieties of cotton, Bt and non-Bt, were grown in Warwat Khanderao in the same crop year, 2006–07. While all studies on the economics of Bt cotton have categorized cotton into two types: Bt and non-Bt (termed local or conventional or traditional), a three-way categorization – Bt cotton, premium (branded) non-Bt cotton, and local non-Bt cotton – was more appropriate to the context that we studied.[9] Bt cotton seeds were sold in packets that contained 400 grams of Bt cotton seeds and 50 grams of non-Bt cotton seeds to be planted as refuge. The prices of packets of Bt cotton seeds of different brands were between Rs 650 and Rs 850 per packet. In contrast, premium non-Bt seeds were normally sold in packets of 750 grams, at Rs 200 to Rs 350 per packet. "Premium non-Bt varieties" can be illegal Bt seeds, genuine hybrids without Bt, or crosses between transgenic and other varieties. Local non-Bt seeds were either recycled from home production or purchased in unpackaged form at Rs 25 to Rs 60 per kilogram. Local non-Bt cotton seeds were thus much cheaper than premium non-Bt cotton seeds.

In this context, a two-fold categorization into Bt and non-Bt would result in clubbing high-yielding non-Bt hybrids together with traditional varieties or older hybrids, and this can be misleading if used to establish the superiority of Bt over other seeds.

Secondly, cotton, including Bt cotton, was grown on separate plots as well as intercropped with other crops. The area under inter-cropping was 65 per cent of gross cropped area and nearly 80 per cent of the area under cotton. In fact, 395 acres (or 160 hectares), accounting for 34.7 per cent of gross cropped area and 43 per cent of area under cotton in the village, was land sown with Bt cotton intercropped with other crops (mainly pulses). According to the *Handbook of Agriculture*, inter-cropping (or strip-cropping) is the traditional practice with cotton cultivation in many parts of Central and South India (ICAR 2006).[10]

Most commonly, rows of cotton were alternated with rows of green gram, black gram, and, in some cases, sorghum. A few rows of red gram were also commonly planted in between. Crops were usually sown in June–July. Green gram and black gram were harvested in August–September when the cotton bushes were still young. Cotton was picked between October and January. Red gram was harvested in January–February after all the cotton had been harvested. Since cotton bushes grow substantially in size, they need to be planted with a space of about 4 feet between rows. Inter-cropping with cotton is particularly economical because in the early stages of plant growth, when the bushes are small and flowering has not yet started, short-duration crops like green gram, black gram, and sorghum can be grown in

9 Some studies differentiate between Bt cotton and conventional cotton (Qaim *et al.* 2006, Bennett *et al.* 2006, Subramanian and Qaim 2009), while some differentiate between Bt cotton and conventional hybrid cotton (Ramasundaram *et al.* 2007, Rao and Dev 2009).

10 The practice of inter-cropping cotton with black gram, green gram, soybean, groundnut, and pigeon pea has been noted in Madhya Pradesh, Maharashtra, and Gujarat (ICAR 2006).

between the rows without reducing the density of cotton bushes. These leguminous plants also helped nitrogen fixation in the soil.

All cultivators maintained the traditional practice of inter-cropping cotton with pulses even after the introduction of Bt cotton. Nevertheless, the proportion of land under inter-cropping was negatively related to farm size (Table 5). In Warwat Khanderao, among marginal and small farms, over 90 per cent of the cotton crop was intercropped with pulses; the proportion fell to 61 per cent for cultivators with over 20 acres. This is not surprising, given that pulses and jowar were mainly grown for self-consumption.

Conversely, of the total area under stand-alone Bt cotton, 69 per cent was cultivated by households with more than 10 acres of operational land, that is, by relatively large farmers, and only 4 per cent by households with less than 2.5 acres.[11] In other words, the practice of growing Bt cotton alone is mainly adopted by cultivators with larger land-holdings.

Thirdly, Bt cotton was grown by both small and large cultivators. Indeed, the proportion of area under Bt cotton was similar across farms of different sizes (Table 4). On average, both small (2.5 to 5 acres) and large farms (10–20 acres) reported about 60 per cent of gross cropped area under Bt cotton. The proportion of area under Bt cotton was lower (46 per cent of cotton gross cropped area) only among very big cultivators (seven households with more than 20 acres each).

RETURNS FROM COTTON CULTIVATION

The features of cropping pattern in the village that we have highlighted above have two important methodological implications. First, we have to separate costs and incomes from cultivation for the three types of cotton. Secondly, on account of inter-cropping, it becomes difficult to estimate the returns to cotton separately from the returns to crops grown along with cotton. We have chosen not to separate the costs for each crop that is part of an intercropped field by following some rule of thumb, such as apportioning costs in the ratio of the gross value of output or seed rate. Some crop operations like ploughing are done jointly, some crop operations like harvesting are done separately, some inputs are applied to the entire field, and some, such as the application of pesticides, may be directed to cotton only. Although we have data on gross incomes for each of the different crops, in our analysis of incomes in this paper, we examine (a) returns from cotton where cotton is grown as a stand-alone crop, and (b) returns from the cotton *farming system* where cotton is cultivated with other crops on the same plot.

11 Packets of Bt cotton seeds contained a small packet of non-Bt seeds to be planted as refuge. A field planted with Bt cotton seeds along with non-Bt refuge has been classified in our analysis as stand-alone Bt cotton. Inter-cropping in this note refers only to row inter-cropping of Bt cotton with other crops.

Table 4 *Share of local non-Bt, premium non-Bt, and Bt cotton in area cultivated with stand-alone and intercropped cotton, by size-class of operational holdings, Warwat Khanderao* in per cent and acres

Size-class of operational holdings (acres)	Local non-Bt	Premium non-Bt	Bt cotton	All cotton	
				Per cent	Acres
>0–2.5	24.5	16.0	59.6	100.0	118
>2.5–5	14.8	26.1	59.1	100.0	200
>5–10	14.7	31.6	53.8	100.0	184
>10–20	13.7	24.9	61.4	100.0	227
20–85	16.9	36.9	46.2	100.0	190
All	16.2	27.8	56.0	100.0	917

Note: Area cultivated includes total area under the crop whether stand-alone or intercropped.

Source: Survey data 2007.

Table 5 *Share of intercropped cotton in total area under cotton by type of cotton and size-class of operational holdings, Warwat Khanderao* in per cent

Size-class of operational holdings (acres)	Local non-Bt	Premium non-Bt	Bt	All cotton
>0–2.5	100.0	100.0	92.9	95.7
>2.5–5	100.0	100.0	86.0	91.7
>5–10	81.4	94.8	84.8	87.5
>10–20	67.7	61.0	75.6	70.9
20–85	17.2	100.0	45.1	60.7
All	72.0	90.2	76.9	79.8

Source: Survey data 2007.

Our estimates of gross incomes, paid-out costs, and net incomes from the cultivation of cotton are shown in Table 6. Since our survey was a census, the reported figures are population averages. As discussed, the returns refer to cotton alone where cotton is grown separately, and to total incomes per acre where cotton is intercropped. In other words, we are comparing the returns per acre to cultivators based on their chosen crop mix and not examining only crop-specific returns.[12]

12 Since inter-cropping is practised widely, it is not clear to us how other studies of crop returns, including the literature on returns from Bt cotton, have separated costs and incomes from crops grown on the same plot.

To estimate net incomes, we deduct costs from the gross value of output (GVO), or the value of all output, crops, and their by-products, on a given unit of cultivated land. Since Bt cotton and other types of cotton were not separated at the time of sale, the prices received by any cultivator at any specific sale were the same irrespective of the variety of cotton grown.

The cost concept used is Cost A2, as defined by the Government of India's Commission on Agricultural Costs and Prices (CACP) (Surjit 2008). Cost A2 includes cost of hired labour, cost of owned and hired animal labour, cost of owned and hired machinery, value of home-produced and purchased seeds, value of plant protection chemicals, value of home-produced and purchased manure, value of all fertilizers used, depreciation of fixed capital, irrigation charges, land revenue, interest on working capital, rent paid for leased-in land, and any other paid-out costs. It does not include any imputed costs of the use of one's own land or any imputed costs of family labour.

Estimate of Gross Incomes

The gross income or gross value of output per acre from the cultivation of Bt cotton (Rs 14,928 per acre or Rs 36,872 per hectare) was much higher than from any other crop or crop combination (Table 6). By way of comparison, Ramasundaram *et al.* (2007) estimated a gross value of output of Rs 26,227 per hectare for Bt cotton cultivators in Vidarbha (in 2002–04). In Kanzara village, the gross value of output from Bt cotton was reported to be Rs 14,323 per acre for the crop year 2006–07 (a figure that is almost identical to our estimate).

On intercropped fields, the gross value of output per acre was Rs 12,485 where Bt cotton was grown, and Rs 11,693 where premium non-Bt cotton was grown. The gross value of output on land under local cotton varieties was much lower, at Rs 7,652 per acre.

On stand-alone fields, the gross value of output from Bt cotton was 101 per cent higher than the gross value of output from local varieties of cotton (Table 7). When only intercropped fields are considered, the gross value of output from Bt cotton fields was 7 per cent higher than the gross value of output from premium non-Bt cotton fields, and 63 per cent higher than on fields with local cotton. On average, on all intercropped plots, the gross income from the mixed crop (say, pulses) was similar, and the differences in gross value of output were thus on account of differences in cotton production. In other words, while Bt cotton outperformed other seeds when grown separately, on intercropped fields, the yields and gross value of output from Bt cotton were only a little higher than from premium non-Bt seeds.

Table 6 *Average farm business incomes, Cost A2 and gross value of output, Warwat Khanderao village, 2006–07* in rupees per acre at current prices

Crop	Gross value of output	Cost A2	Farm business incomes
Stand-alone cotton			
Bt cotton (stand-alone)	14,928	7,869	7,059
Local non-Bt cotton (stand-alone)	7,418	3,835	3,583
Intercropped cotton			
Bt cotton intercropped with other crops	12,485	6,130	6,355
Premium non-Bt cotton intercropped with other crops	11,693	4,964	6,729
Local non-Bt cotton intercropped with other crops	7,652	3,269	4,382
Stand-alone and intercropped combined			
Bt cotton (stand-alone and intercropped)	13,059	6,539	6,520
Premium non-Bt cotton (stand-alone and intercropped*)	11,213	5,031	6,183
Local non-Bt cotton (stand-alone and intercropped)	7,571	3,465	4,106
Wheat	11,830	6,742	5,088
Sorghum	6,084	3,929	2,155
Pulses (stand-alone)	12,519	5,254	7,264
All crops	11,249	5,479	5,770

Notes: *As very few households cultivated premium non-BT varieties as a stand-alone crop, we have not shown the estimates separately.
Source: Survey data 2007.

Table 7 *Percentage difference in gross value of output, cost A2 and net income between Bt cotton, premium non-Bt cotton and local non-Bt cotton, Warwat Khanderao*

Variable	Stand-alone Bt cotton relative to local cotton	Intercropped Bt relative to intercropped local cotton	Intercropped Bt relative to intercropped premium non-Bt
GVO	101	63	7
Cost A2	105	87	23
Net incomes	97	45	-6

Source: Survey data 2007.

Costs

Of all crop combinations, costs of cultivation (Cost A2) were the highest for Bt cotton grown as a single crop (Rs 7,869 per acre).[13] Costs of cultivation were the lowest for local non-Bt cotton and jowar (Table 7). The source of high costs in Bt cotton becomes clearer when we examine item-wise costs (see Table 8).

First, as expected, costs of seed were the highest for Bt cotton, the second highest for premium non-Bt cotton, and the lowest for local non-Bt cotton. Expenditure on seeds is a major component of expenditure on cultivation of Bt cotton, second only to labour costs.

Secondly, and contrary to what we expected, costs of pesticides and insecticides (or what is termed plant protection chemicals) were much higher for Bt cotton than for non-Bt cotton in both absolute and proportionate terms. For example, where Bt cotton was grown separately, costs of chemicals amounted to Rs 1,041 per acre, accounting for 13 per cent of total input costs. By contrast, on fields with premium non-Bt cotton, costs of pesticides amounted to Rs 622 per acre (or 11 per cent of total paid-out costs). These costs were the lowest for local cotton (Rs 277 per acre).

As shown in Table 1, all previous studies showed that costs of pesticides were lower in absolute terms for Bt cotton than for other types of cotton. In a Vidarbha study, pesticide costs amounted to Rs 1,133 per hectare for Bt and Rs 2,402 per hectare for conventional cotton (Ramasundaram *et al.* 2007). Our study differs in this respect (see also, Ramakumar *et al.* 2009).[14]

The reasons for high use of pesticides on Bt fields may be many, including the presence of pests other than bollworm (for which Bt provides resistance), wrong or ignorant farming practices, the risk-averseness of cultivators (leading to precautionary spraying because of high investment in cultivation of Bt varieties), and so on. Nevertheless, it is a fact that in Warwat Khanderao, the application of pesticides and costs of pesticide application were not lowered with the adoption of Bt cotton.

Our survey also showed that input dealers and marketing agents of seed companies were the main source of information on agricultural inputs and farming practices. Of all households in the village that operated land, 46 per cent reported that the main source of information on farming practices were input dealers and seed companies. Seed companies organized training camps where farmers were told about the new varieties available. Another 24 per cent of cultivators said they obtained information from other farmers. Fifteen per cent of cultivators said they listened to radio

13 Our estimate of cost is higher than that reported for Dongargaon village (Rs 5,791 per acre) by Ramakumar *et al.* (2009).
14 It was reported that, in Kanzara village, the quantity of insecticides used on Bt cotton was 21 per cent less than the quantity of pesticides used on conventional cotton, but the reported figure is in kilograms, and it is not clear how liquids of different concentration were converted into kilograms (Subramanian and Qaim 2010).

Table 8 *Average cost of cultivation of Bt and non-Bt cotton, by item, Warwat Khanderao village, 2006–07,* in rupees per acre at current prices

Item	Bt cotton (stand-alone)	Local non-Bt cotton (stand-alone)	Bt cotton intercropped	Premium non-Bt cotton intercropped	Local non-Bt cotton intercropped
Seed	1041	121	1002	692	271
Manure	596	241	347	217	164
Fertilizer	847	550	605	583	352
Plant protection chemicals	1014	277	706	**495**	**113**
Irrigation	42	0	8	0	0
Hired labour	2629	1267	1959	1902	1320
Machinery	178	283	281	202	238
Animal labour	568	288	536	355	466
Rent	253	337	155	52	114
Marketing expenses	8	0	19	13	14
Crop insurance	4	0	10	1	2
Taxes	17	3	22	29	23
Interest on working capital	283	138	230	182	123
Depreciation	320	298	213	193	61
Maintenance	50	31	28	35	7
Miscellaneous expenses	19	0	10	13	1
Cost A2	7869	3835	6130	4964	3269

Source: Survey data 2007.

programmes or watched television programmes on agriculture, but seldom did they get information relevant to their needs. Seven per cent of households said they obtained some information from newspapers and magazines. Only 11 per cent of cultivating households obtained information from extension workers or any public institution.

Net Incomes

In Warwat Khanderao, the net income or farm business income from stand-alone Bt cotton fields was Rs 7,059 per acre or Rs 17,435 per hectare (equivalent to 425 USD per hectare at the June 2007 exchange rate). Qaim and Subramanian (2010) report a net income of Rs 7,120 per acre in Kanzara for the same year, and Ramakumar *et al.* report a net income of Rs 7,575 per acre. The estimates from the three village studies are remarkably close and provide credibility to our data. They are also higher than the estimates for earlier years for the same region (Ramasundaran *et al.* 2007).

In absolute terms, the difference in net incomes between Bt and local varieties of cotton was around Rs 3,400 per acre. For Kanzara village, according to Subramanian and Qaim (2010), per acre net revenues were on average Rs 2,000–3,000 higher on Bt than on conventional cotton plots.

The income advantage of Bt cotton fell with inter-cropping. On intercropped plots, the gross value of output per acre from intercropped Bt cotton was only slightly higher than from intercropped premium non-Bt cotton, but as costs were also higher, net incomes became slightly lower (Rs 6,355 an acre from intercropped Bt cotton and Rs 6,729 per acre from intercropped premium non-Bt cotton; Table 6).

With one exception (Ramakumar *et al.* 2009), existing studies on the economics of Bt cotton have not dealt with the issue of inter-cropping and its implications for yields and returns. As shown in Table 3, 79 per cent of the cotton area of the village is under mixed crops, and only 21 per cent under pure cotton. Inter-cropping is thus the dominant local cultivation practice, as is also the case in other unirrigated areas of Maharashtra.[15] The economics of intercropped cotton needs further research.

Cotton prices fluctuate from year to year, and have crashed in several years, resulting in big losses to cultivators. The median price from our survey data was Rs 1,900 per quintal, close to the minimum support price for long-staple cotton that year.[16] Thus, in a "normal" year, it is clear that the cultivation of both Bt cotton and premium non-Bt cotton was profitable even in a rainfed village, bringing in at least Rs 6,000 an acre. It is surprising, then, to find that the estimates of net incomes (farm business incomes) reported in official data for Maharashtra are much lower (only a single average income is reported, aggregated over types of seed and availability of

15 This is recognized in earlier (pre-GM cotton) research (ICAR 2006).
16 See Ramakumar *et al.* (2009).

irrigation). In 2005–06, according to CACP data, net income from cotton cultivation in Maharashtra was Rs 1,659 per acre.[17]

MULTIVARIATE REGRESSION

The preliminary statistical analysis indicates that differences in costs and incomes relate not only to choice of seed, but also to variations in crop mix, pattern of input use and farming practices. The latter, in turn, depend on many factors, including size of operational holding. In order to look at the combined effect of different variables on gross output and net incomes, we estimated the following regressions.

First, we estimated an ordinary least squares (OLS) equation with gross value of output (GVO) per acre as the dependent variable (Appendix Table A1). The independent variables included size of land-holding, caste, expenditure on specific inputs, and type of cotton-farming system. To accommodate actual cultivation practices, we took intercropped Bt cotton as the default and introduced dummy variables for all other cotton crop combinations. Since there was significant heteroscedasticity in this model, tests of significance were done using White's heteroscedasticity corrected covariance matrix. All the variables are defined in Appendix Table A5.

The results show that size of operational holding has a positive effect on gross value of output. Secondly, additional application of fertilizers and pesticides per unit of land has a positive impact on gross value of output. Thirdly, the gross value of output was lower among Muslim households than all other social groups in the village. This can be explained by the fact that all the Muslim households (and some of the Dalit households) owned land by the side of the river, land that was reported to be of inferior quality. The social group variable was probably picking up differences in the quality of land. Lastly, local non-Bt cotton, when cultivated as a stand-alone crop or when intercropped with other crops, resulted in a lower gross value output than intercropped Bt cotton, but the gross value of output per acre from intercropped premium non-Bt cotton was not significantly different from that of intercropped Bt cotton. As noted earlier, in this village, the major part of gross cropped area was intercropped.

A second regression was undertaken using the logarithm of the gross value of output per acre as the dependent variable (Appendix Table A2). The logarithmic transformation removed skewness and thus the problem of heteroscedasticity. However, we had to eliminate eight observations where the crop had failed completely and gross value of output, consequently, was zero. The results are similar to the previous model except for one. In the logarithmic model, intercropped premium non-Bt cotton showed a significantly lower gross value of output than intercropped Bt cotton.

17 The CACP estimates of Cost A2 are similar to our average for the village, but their estimated gross income is much lower than our estimate.

Based on these two regressions, it can be argued that intercropped Bt cotton resulted in a higher gross value of output than all other non-Bt cotton crop combinations.

In terms of incomes, however, the picture is different. In Appendix Table A3, we report the results of an OLS regression with net income per acre as the dependent variable. There was heteroscedasticity in this model as well, and therefore tests of significance were done using White's heteroscedasticity corrected covariance matrix. Since net income takes negative values for a sizeable number of observations (19 out of 260), and because negative incomes reflect a phenomenon that we did not want to ignore, a logarithmic transformation of net income was not used.

The size of operated land had a positive effect on net incomes per acre. Most importantly, all the intercropped plots, whether using Bt or other types of cotton, did not differ significantly in terms of net incomes per acre. Only when local non-Bt cotton was grown as a stand-alone crop (not a common practice) were the returns lower than on intercropped Bt cotton plots. To put it differently, after adjusting for farm size and input use, net returns from intercropped fields were similar across types of cotton, and also similar to returns from stand-alone Bt cotton fields.

Lastly, we estimated separate regressions for four major cotton crop combinations: stand-alone Bt cotton, intercropped Bt cotton, intercropped premium non-Bt cotton, and intercropped local non-Bt cotton (Appendix Table A4). Interestingly, the factors affecting gross value of output differed in the four types of fields. The size of land-holding was significant for intercropped premium non-Bt cotton. On stand-alone Bt cotton plots, the gross value of output gained by Dalit households was significantly lower than the gross value of output gained by households from Other Backward Classes. Plant protection chemicals gave a boost to gross value of output on intercropped Bt plots, while fertilizers made an impact on intercropped local cotton.

The residual standard errors of the regressions for each type of crop mix show that, after controlling for variations in expenditure on various inputs and the influence of socio-economic differences, the residual variation in the gross value of output – a measure of production uncertainty – was highest for Bt cotton, whether stand-alone or intercropped, and lowest for local non-Bt cotton (Table A6). Specifically, production uncertainty in the cultivation of intercropped Bt cotton was about 55 per cent higher than production uncertainty in the cultivation of local non-Bt cotton. Production uncertainty in the cultivation of premium non-Bt cotton was about 30 per cent higher than production uncertainty in the cultivation of local non-Bt cotton.

CONCLUDING REMARKS

This note examines farm business incomes from Bt cotton in field conditions in a rainfed village in the Vidarbha region of Maharashtra, where the majority of cultivators operated less than 5 acres of land. While our results cannot be compared with the findings of multi-state sample surveys, we believe there are some valuable findings in this village study.

In Maharashtra, the State with the largest cotton acreage in the country, over 90 per cent of the cotton is grown under rainfed conditions. Our village study provides an evaluation of the gains from Bt cotton (or farm business incomes from Bt cotton) based on its cultivation as an *unirrigated* crop.

Any evaluation of the economics of Bt cultivation must also take into account the fact that a very substantial proportion of cotton cultivation is on land that is *intercropped* with cereals and pulses. Cultivation of cotton alongside green gram or other pulses, and sorghum or finger millet is a common practice in Central and South India (ICAR 2006). In our study village, 79 per cent of the cotton was grown on intercropped fields. Inter-cropping was particularly prevalent among small and marginal farmers (poor and middle peasants), for whom inter-cultivation was a strategy that reserved a part of their total product for subsistence and another part for commercial sale. By contrast, it was mainly big cultivators who grew Bt cotton as a stand-alone crop (Table 5).

In this paper, we divide cotton cultivation into three types: Bt cotton, local cotton, and non-Bt premium cotton (something of a grey zone of non-Bt hybrids and Bt pollinated on fields). There were clear differences in the price of seeds as between these three types of cotton.

When grown alone, Bt cotton was the clear and unequivocal leader in terms of yields, production, gross value of output, and net income. When mono-cropped, the gross value of output from Bt cotton was 101 per cent higher than from local cotton, and despite higher costs, net incomes were 97 per cent higher (Table 7). This concurs with the findings of other studies (Rao and Dev 2009). In absolute terms, our estimate of gross value of output from stand-alone Bt cotton is very close to that of Qaim and Subramaniam for Kanzara village, though higher than the gross value of output reported in official reports. However, as already noted, Bt cotton was grown as a single crop only on 10 per cent of the gross cropped area, and mainly by big cultivators.

When intercropped, the relative income advantage of Bt cotton declined. Thus, most marginal and small farmers, for whom it is an inter-crop, did not get the full advantage of the transition to Bt cotton. An important reason for this is the relatively high cost of cultivation associated with Bt cotton. There are issues here for further research by agronomists.

When disaggregated, seed costs for Bt were higher than for other types of cotton, as expected. What was surprising and not predicted by the data from other studies was the high absolute expenditure on pesticides, and the high share of pesticides in total input cost of Bt cotton cultivation (Table 8). On average, on intercropped fields, for example, the expenditure on pesticides was Rs 706 per acre for Bt cotton and Rs 495 per acre for premium non-Bt cotton (that is, 43 per cent higher for Bt cotton). Absolute costs of pesticides were even higher on stand-alone Bt cotton plots. Expenditure on seeds, fertilizers, and pesticides together accounted for 37 per cent of the total costs of Bt cotton cultivation (whether grown alone or intercropped). For premium non-Bt cotton, these costs amounted to 34 per cent of the total costs.

While there can be many reasons for the high costs of cultivation, the absence of adequate agricultural information from public sector extension workers is clearly one of the important reasons. In Warwat Khanderao village, we found a heavy dependence of cultivators on seed companies and input merchants for information on farming practices. The decline in public extension and information services, and their privatization, has been an important component part of the liberalization and globalization package in India.

Lastly, a regression exercise was undertaken to examine the combined effect of farm size, crop mix, and input use on output and incomes. The results showed that farm size had a significant positive effect on gross value of output and net incomes. Further, while fields with intercropped Bt cotton reported a higher gross value of output than all other cotton crop combinations, in terms of net incomes, the results were not as clear-cut. There was a clear income advantage from the cultivation of Bt cotton over local cotton, but the advantage over fields with premium non-Bt cotton was not statistically significant. Thus, after adjusting for farm size and input use, net returns from intercropped fields were similar across types of cotton, and also similar to returns from stand-alone Bt cotton fields.

Our study showed that farmers in Warwat Khanderao village, particularly small farmers, were unable to gain the full benefits of a higher gross value of output from the new cotton technology. Farming practices and the economics of the cultivation of Bt cotton are not static: they change from year to year, and vary from region to region. Research from the Project on Agrarian Relations in India will continue to examine socio-economic issues in cotton cultivation in different parts of India.

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APPENDIX TABLES

Table A1 *Results of the OLS regression model with dependent variable: gross value of output per acre*

	Estimate	Std. error	t-value	Pr(>|t|)
(Intercept)	8550.51	860.08	9.94	0.00000***
Operational holding	90.99	23.67	3.84	0.00015***
Nomadic tribe	−1217.34	804.42	−1.51	0.13152
Scheduled Caste	−550.21	1432.39	−0.38	0.70123
Muslim	−3245.22	693.34	−4.68	0.00000***
Cost of manure per acre	1.10	0.77	1.42	0.15567
Cost of fertilizer per acre	2.05	1.00	2.06	0.04090*
Cost of plant protection per acre	2.31	0.82	2.80	0.00548**
Cost of irrigation per acre	−1.84	2.75	−0.67	0.50430
Cost of machine labour per acre	2.22	1.65	1.35	0.17956
Cost of animal labour per acre	0.19	0.52	0.36	0.71957
BT (stand-alone)	−199.65	1145.60	−0.17	0.86180
Local non-BT (stand-alone)	−7991.88	1184.07	−6.75	0.00000***
Premium non-BT (intercropped with other crops)	−1208.55	748.65	−1.61	0.10778
Local non-BT (intercropped with other crops)	−1845.90	842.86	−2.19	0.02949*
Residual standard error: 4612 on 239 degrees of freedom				
Multiple R-squared: 0.3994, Adjusted R-squared: 0.3642				
F-statistic: 11.35 on 14 and 239 DF, p-value: < 2.2e−16				

Notes: Signif. Codes: '***' 0.001 '**' 0.01 '*' 0.05
The tests of significance have been done using White's heteroscedasticity corrected covariance matrix.

Table A2 *Results of the OLS regression model 1B, dependent variable: log (gross value of output per acre)*

	Estimate	Std. error	t-value	Pr(>$\lvert t\rvert$)
(Intercept)	8.9977	0.0813	110.72	0.0000***
Operational holding	0.009	0.0028	3.21	0.0015**
Nomadic tribe	−0.1527	0.0781	−1.96	0.0517
Scheduled Caste	0.0953	0.1325	0.72	0.4726
Muslim	−0.2904	0.0835	−3.48	0.0006***
Cost of manure per acre	0.0001	0.0001	1.76	0.0797
Cost of fertilizer per acre	0.0002	0.0001	2.06	0.0402*
Cost of plant protection per acre	0.0002	0.0001	2.6	0.0100**
Cost of irrigation per acre	−0.0002	0.0002	−0.77	0.4413
Cost of machine labour per acre	0.0002	0.0001	2.25	0.0254*
Cost of animal labour per acre	0	0	0.89	0.3733
BT (stand-alone)	−0.0232	0.094	−0.25	0.8053
Local non-BT (stand-alone)	−1.1115	0.1994	−5.57	0.0000***
Premium non-BT (intercropped with other crops)	−0.152	0.0762	−1.99	0.0472*
Local non-BT (intercropped with other crops)	−0.2781	0.0958	−2.9	0.004**
Residual standard error: 0.4441 on 231 degrees of freedom				
Multiple R-squared: 0.4048, Adjusted R-squared: 0.3687				
F-statistic: 11.22 on 14 and 231 DF, p-value: < 2.2e−16				

Notes: Signif. Codes: '***' 0.001 '**' 0.01 '*' 0.05.

Table A3 *Results of the OLS regression model with dependent variable: net income per acre*

	Estimate	Std. error	t-value	Pr(>|t|)
(Intercept)	6607.56	810.37	8.15	0.00000***
Operational holding	55.33	23.48	2.36	0.01928*
Nomadic tribe	−942.23	816.81	−1.15	0.24984
Scheduled Caste	−584.79	1384.59	−0.42	0.67314
Muslim	−3267.01	664.68	−4.92	0.00000***
Cost of manure per acre	−0.04	0.69	−0.06	0.95552
Cost of fertiliser per acre	0.17	0.92	0.18	0.85654
Cost of plant protection per acre	0.52	0.79	0.65	0.51351
Cost of irrigation per acre	−3.21	3.19	−1.01	0.31402
Cost of machine labour per acre	0.23	1.36	0.17	0.86274
Cost of animal labour per acre	−0.74	0.49	−1.53	0.12772
BT (stand-alone)	17.29	1065.24	0.02	0.98706
Local non-BT (stand-alone)	−6023.14	1124.89	−5.35	0.00000***
Premium non-BT (intercropped with other crops)	−642.61	727.38	−0.88	0.37788
Local non-BT (intercropped with other crops)	−927.58	811.85	−1.14	0.25437
Residual standard error: 4439 on 239 degrees of freedom				
Multiple R-squared: 0.1829, Adjusted R-squared: 0.1351				
F-statistic: 3.822 on 14 and 239 DF, p-value: 7.497e−06				

Notes: Signif. Codes: '***' 0.001 '**' 0.01 '*' 0.05.
The tests of significance have been done using White's heteroscedasticity corrected covariance matrix.

Table A4 *Results of the OLS regression models estimated separately for different types of cotton, dependent variable: gross value of output per acre*

	BT (stand-alone)	BT (intercropped with other crops)	Premium non-BT (intercropped with other crops)	Local non-BT (intercropped with other crops)
(Intercept)	15430.73***	8433.63***	4796.14*	4913.89*
Operational holding	89.18	75.78	120.77*	−31.83
Nomadic tribe	−5603.37	−1729.71	1703.25	−3395.47
Scheduled Caste	−19232.96**	1434.14	−2733.79	−2089.49
Muslim	−5236.79	−3146.66*	−2157.88	−3401.58*
Cost of seeds per acre	−7.34*	0.35	2.51	4.36
Cost of manure per acre	−0.49	1.42	0.20	1.89
Cost of fertilizer per acre	2.46	1.47	−0.01	5.85*
Cost of plant protection per acre	2.21	2.29*	3.20	0.09
Cost of irrigation per acre	0.86	0.15	NA	NA
Cost of machine labour per acre	12.66*	1.57	5.78	5.79
Cost of animal labour per acre	−0.24	0.75	−0.16	-0.29
Degrees of freedom	22	107	45	26
Residual standard error	4751	5036	4204	3234
Adjusted R-squared	0.4559	0.1569	0.233	0.4895

Notes: Signif. Codes: '***' 0.001 '**' 0.01 '*' 0.05.

No irrigation was used on fields planted with premium and ordinary non-BT cotton.

Table A5 *Variables used in the regression models*

Explanatory variables	
Operational holding	Acres
Nomadic tribe	1 if social group=Nomadic tribe, 0 otherwise
Scheduled Caste	1 if social group=Scheduled Caste 0 otherwise
Muslim	1 if social group=Muslim, 0 otherwise
Nomadic tribe=Scheduled Caste=Muslim=0 if the household belonged to OBC	
Cost of manure per acre	Rs per acre
Cost of fertilizer per acre	Rs per acre
Cost of plant protection per acre	Rs per acre
Cost of irrigation per acre	Rs per acre
Cost of machine labour per acre	Rs per acre
Cost of animal labour per acre	Rs per acre
BT (stand-alone)	1 if stand-alone BT cotton, 0 otherwise
Local non-BT (stand-alone)	1 if stand-alone Ordinary non-BT cotton, 0 otherwise
Premium non-BT (intercropped with other crops)	1 if Premium non-BT cotton intercropped with other crops, 0 otherwise
Local non-BT (intercropped with other crops)	1 if Local non-BT cotton intercropped with other crops, 0 otherwise
BT (stand-alone) = Local non-BT (stand-alone) = Premium non-BT (intercropped with other crops) = Local non-BT (intercropped with other crops) = 0 if BT cotton (intercropped with other crops) was cultivated.	

Table A6 *Residual standard errors, regressions with gross value of output per acre as the dependent variable*

Type of cotton	Residual standard error
BT cotton stand-alone	4751
BT cotton intercropped with other crops	5036
Premium non-BT cotton intercropped with other crops	4204
Local non-BT cotton intercropped with other crops	3234
All cotton	4612