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Inequality and GM Crops: A Case-Study of Bt Cotton in India

Stephen Morse, Richard Bennett, and Yousouf Ismael
University of Reading, United Kingdom

Critics of genetically modified (GM) crops often contend that their introduction enhances the gap between rich and poor farmers, as the former group are in the best position to afford the expensive seed as well as provide other inputs such as fertilizer and irrigation. The research reported in this paper explores this issue with regard to Bt cotton (cotton with the endotoxin gene from *Bacillus thuringiensis* conferring resistance to some insect pests) in Jalgaon, Maharashtra State, India, spanning the 2002 and 2003 seasons. Questionnaire-based survey results from 63 non-adopting and 94 adopting households of Bt cotton were analyzed, spanning 137 Bt cotton plots and 95 non-Bt cotton plots of both Bt adopters and non-adopters. For these households, cotton income accounted for 85 to 88% of total household income, and is thus of vital importance. Results suggest that in 2003 Bt adopting households have significantly more income from cotton than do non-adopting households (Rp 66,872 versus Rp 46,351) but inequality in cotton income, measured with the Gini coefficient (G), was greater amongst non-adopters than adopters. While Bt adopters had greater acreage of cotton in 2003 (9.92 acres versus 7.42 for non-adopters), the respective values of G were comparable. The main reason for the lessening of inequality amongst adopters would appear to be the consistency in the performance of Bt cotton along with the preferred non-Bt cultivar of Bt adopters – Bunny. Taking gross margin as the basis for comparison, Bt plots had 2.5 times the gross margin of non-Bt plots of non-adopters, while the advantage of Bt plots over non-Bt plots of adopters was 1.6 times. Measured in terms of the Gini coefficient of gross margin/acre it was apparent that inequality was lessened with the adoption of Bunny (G = 0.47) and Bt (G = 0.3) relative to all other non-Bt plots (G = 0.63). Hence the issue of equality needs to be seen both in terms of differences between adopters and non-adopters as well as within each of the groups.

Key words: inequality, Gini coefficient, India, genetic modification (GM), Bt cotton.

Introduction

Farmers are not all the same. Some are more willing to take risks and adopt new technology than others, while some are simply better farmers than others. This has been the case since the birth of agriculture, but debates surrounding 'inequality' have, if anything, become more intense in the past 10 years with the increasing popularity of genetically modified (GM) crops. Proponents argue that GM crops represent a major breakthrough in the fight against famine and poverty (Delmer, 2005) and their economic and other advantages to farmers explains their popularity wherever they have been released (Raney, 2006), while critics argue that GM adopters are more likely to be the 'better' farmers (in terms of education, ability, interest, access to resources, etc.) within the community. Hence 'better' farmers get richer while those farmers unable to take the risks and provide the necessary investment get poorer. Thus, inequality is exacerbated. But what is the evidence for such inequality, both in terms of adoption of GM varieties and the benefits, if any, that they provide?

Estimating 'inequality' amongst households is a complex field of study, and has not, as yet, been the centerpiece of GM research in developing countries. Instead, the focus has been more upon the impact of GM crops assessed in economic terms across different categories of farmer, typically on a per hectare/acre basis. There are, of course, moral dimensions to this issue as well as material concerns such as the potential for social tension (Quadrado et al., 2001). The typical focus within many studies of inequality is upon income, but it has to be stressed that inequality can be considered in terms of other factors such as education, health care, assets, quality of the natural environment, expenditure, etc. (Sen, 1985; Cohen, 2000). There are a number of measures of equality of distribution of income amongst individuals

Table 1. Example studies showing a significant economic advantage from growing Bt cotton in developing countries.

Country	References
South Africa	Ismael, Bennett, and Morse (2002a, 2002b); Bennett, Buthelezi, Ismael, and Morse (2003); Bennett, Kambhampati, Morse, and Ismael (2006); Thirtle, Beyers, Ismael, and Piesse (2003); Morse, Bennett, and Ismael (2004, 2005b)
Argentina	Qaim and De Janvry (2005)
Mexico	Traxler, Godoy-Avilla, Falck-Zepeda, and Espinoza-Arellano (2001)
Indonesia	Manwan and Subagyo (2001)
China	Pray, Rozelle, Huang, and Wang (2002a); Pray, Huang, Hu, and Rozelle (2002b); Yang, Iles, Yan, and Jolliffe (2005a); Yang, Li, Shi, Xia, Gua, Li, et al. (2005b)
India	Naik (2001); Qaim (2003); Qaim and Zilberman (2003); Pemsl, Waibel, and Orphal (2004); Bennett, Ismael, Kambhampati, and Morse (2004); Bennett, Ismael, Morse, and Shankar (2005); Barwale, Gadwal, Zehr, and Zehr (2004); Morse, Bennett, and Ismael (2005a)

within a population, and there is substantial literature which discusses their relative merits (Atkinson, 1970). Perhaps the simplest way of approaching this is to first rank the population in terms of income (or whatever) category and then consider the proportion of income associated with that category. The difference between the proportion of individuals in a category and the proportion of wealth in that same category will provide some idea as to the extent of equality.

In order to address this question, the paper will focus on a case study of Bt cotton in Jalgoan, India. Bt cotton utilizes a gene from the bacterium *Bacillus thuringiensis* (Bt) that codes for proteins (endotoxins) toxic to bollworm (Lepidoptera; *Helicoverpa zea, H. armigera, Diparopsis castenea, Earias biplaga* and *E. insulana*). In India the Bt gene is typically marketed as a component within a background of heterosis (hybrid vigor). If farmers attempt to save seed (not easy with cotton given that seeds have to be separated from lint) then the yield of the F2 generation will be reduced as hybrid vigor diminishes. It should also be noted that Bt-based resistance does not eliminate the need for insecticide as older instars of the bollworm larvae are more able to tolerate the endotoxin. At the time of writing it has been well-established that Bt cotton provides substantial economic benefits for small-scale farmers in developing countries

Table 2. Stratification of respondents and cotton plots.

	Adopters				Non-adopters	
	Bt plots		Non-Bt plots		Non-Bt plots	
	2002	2003	2002	2003	2002	2003
Number of plots	38	51	30	18	45	50
Total number of plots	137				95	
Number of respondents	94				63	

(James, 2002; Table 1). In part this comes from a reduction in costs (less insecticide) but an increase in gross margin is mostly due to higher yields of Bt cotton compared to non-Bt. Nonetheless there are significant reports to the contrary (Orton, 2003; Gala, 2005). Assuming that Bt cotton does provide economic advantages for farmers, and its adoption has certainly been rapid, then it provides an opportunity to test the 'inequality' question raised above.

Methodology

The research reported here was based on a questionnaire survey conducted in the district of Jalgaon situated in the north of Maharashtra State. Jalgaon is an important center for cotton-textile and vegetable-oil mills, particularly groundnut oil and hydrogenation plants. With an area of about 11,700 sq km, Jalgaon District has a population of about 4 million. Jalgaon is divided into 15 sub-districts, known as Talukas, and has 1,475 villages. There are two species of cotton grown in Jalgaon: *G. hirsutum* and *G. arboreum*. Some 73% of the cotton area is planted to an intra-*hirsutum* hybrid. Three Mahyco-Monsanto Bt cotton hybrids were introduced in the 2002 growing season: MECH-162 Bt, MECH-184 Bt and MECH-12 Bt. Popular non-Bt varieties are Bunny, Tulsi, NHH-44 and JK-666. Cotton is planted in June and harvested in November and December.

A survey of 450 cotton producers in two talukas, Parola and Darangaon, in Jalgaon District was undertaken during April and May 2004. The questionnaire focused on the first two cotton-growing seasons following the commercial introduction of Bt hybrids: 2002 and 2003. Experienced personnel were selected to implement the survey. They were trained for two days as well as conducted a pilot study on three cotton producers who were not included in the final sample.

All respondents were selected randomly. Respondents were classified into 'adopters' and 'non-adopters'

Table 3. Income and assets of the households included in the research (data relate to 2003).

		N	Mean	SD	t-value	Gini coefficient
Value of all land owned (Rp)	**Non-adopters**	42	504,643	462,772	1.86 df = 73	0.408
	Adopters	51	797,941	1,004,664	P = 0.067	0.425
Non-land assets (Rp)	**Non-adopters**	41	121,876	139,087	1.24 df = 59	0.44
	Adopters	51	212,921	499,323	ns	0.549
Cotton income (Rp)	**Non-adopters**	41	46,351	40,408	2.18 df = 86	0.412
	Adopters	48	66,872	48,394	P < 0.05	0.34
Total household income (Rp)	**Non-adopters**	42	62,558	70,182	1.06 df = 86	0.444
	Adopters	50	78,118	69,446	ns	0.392
Cotton income as % of total	**Non-adopters**	41	88.1	22.8	0.61 df = 76	0.07
HH income	**Adopters**	48	85.4	18.3	ns	0.074
Land area cultivated (acres)	**Non-adopters**	42	7.42	6.91	1.29 df = 83	0.37
	Adopters	51	9.92	11.56	ns	0.416

of Bt cotton. Adopters were those who had planted at least one plot of Bt cotton in season 2002 and/or 2003. Thus, a farmer who had planted a plot of Bt cotton in 2002 but not in 2003 was still classified as an 'adopter.' Adopters made up the majority of the sample largely because of the popularity of the Bt hybrids in the area. Non-adopters were those who had not planted a plot of Bt cotton in either 2002 or 2003. Where possible, plots of Bt and non-Bt were sampled for the same respondent so as to minimize any effect arising from the farmer's background, such as entrepreneurial ability, age, experience and expertise in growing the crop, along with access to other inputs such as credit and irrigation. However, this was not possible where the whole farm was planted to Bt or non-Bt cotton. The original sample comprised a total of 450 farmers (300 adopters and 150 non-adopters) and 932 cotton plots for the two cotton seasons. However, problems emerged with the original sampling frame given that much was dependent upon memory from the 2002 and 2003 seasons. Thus the information collected was sometimes incomplete. In order to avoid any bias that could emerge with incomplete datasets, only the complete records available for respondents and plots were included in the analysis, and the final sample is as shown in Table 2.

The questionnaire included questions on cotton inputs (seed, insecticide, fertilizer, labor) and output (yield, revenue) for each cotton plot included in the survey, and gross margin was calculated as revenue – total costs. Data analysis was centered on comparisons between Bt and non-Bt plots, and comparison was via a one-way ANOVA (all data transformed by logarithms). The significance level was taken to be 0.05, but significance levels of less than 0.1 but greater than 0.05 were also reported where applicable. Inequality of gross margin/acre was estimated using the Gini coefficient (G):

$$G = 1 - \sum (\sigma X_{i} - \sigma X_{i-1})(\sigma Y_{i-1} + \sigma Y_{i}) \qquad (1)$$

i = label for five gross margin/plot quintiles,
σX_i = cumulated values for population up to category i
σY_i = cumulated values for income up to category i

Values of G range between 0 (complete *equality* in gross margin/plot) and 1 (complete *inequality* in gross margin/plot).

Results

Only a few differences in terms of general background features of the farmer and household were discernible between adopters and non-adopters of Bt cotton. There were no significant differences between adopters and non-adopters in terms of age, farming experience and education of respondent. In terms of household family labor there was some suggestion (P < 0.1) that adopters had more full-time and male labor available for agriculture than did the non-adopters.

Table 3 presents some findings for the samples of non-adopter and adopter households (HH) over a range of asset and income variables. In terms of the total value of land owned there is some evidence (t = 1.86, P = 0.067) that adopting HH had more than did the non-

Table 4. Production and cost statistics for Bt and non-Bt plots of adopters and non-adopters.

	Bt plots of adopters				Non-Bt plots of adopters				Non-Bt plots of non-adopters			
	2002		2003		2002		2003		2002		2003	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Yield (quintles/acre)	7.67	3.16	8.16	2.94	5.37	2.22	6.43	4.6	4.15	2.53	4.49	2.69
Revenue (Rp/acre)	17,259	8,094	18,900	7,503	11,298	5,124	14,117	10,494	8,576	5,756	9,592	5,973
Costs (Rp/acre)												
Seed	1,423	617	1,356	373	463	128	512	175	417	112	415	137
Total fertilizer	876	591	976	850	1066	874	1,770	4,067	892	592	967	731
Bollworm insecticide	487	798	314	330	442	445	776	1,388	517	491	450	474
Irrigation	55	74	90	157	99	220	104	171	30	54	45	74
Total labor	2,033	1,093	2,116	1,337	1,652	1,001	2,741	2,512	1,723	1,099	1,815	1,240
Total costs	**4,736**	**2,074**	**4,852**	**2,589**	**3,409**	**2,270**	**5,636**	**7,749**	**3,622**	**1,948**	**3,636**	**2,303**
Gross margin (Rp/acre)	12,523	7,749	14,048	7,672	7,889	5,007	8,481	12,877	4,954	5,662	5,956	6,172
Sample size	38		51		30		18		45		50	

adopters, a difference largely due to the former having more land rather than their land being of higher value per unit. The values of G for the two categories of HH are comparable; equality in distribution is more or less the same for the two. For the non-land assets (buildings, machinery, etc.) adopting HH again seemed to have more although this time the difference was not significant. The biggest difference between the two groups is with cotton income (total revenue – costs of production). Adopting HH have a significantly higher income from cotton (44% greater) than do non-adopters. Not only is there a difference in mean cotton income but the values of G are also quite different (0.34 for adopters and 0.412 for non-adopters), suggesting that HH within the adopter category have a more *equal* distribution of cotton income than do non-adopters. The importance of this finding is highlighted by the fact that for both categories of HH, cotton income makes up by far the largest share (between 85 and 88%) of total income. Thus, what happens with cotton is of vital importance to these households. While the mean total HH income for adopters was higher than that of non-adopters (and G was again lower) the difference was not significant. This is probably a reflection of the difficulty of obtaining accurate estimates of non-cotton income that makes up 12 to 15% of HH income than anything else. Thus standard deviations tend to be high.

So what has resulted in this greater equality of cotton income amongst the adopter group of HH relative to the non-adopters? Is it due to greater equality in land ownership? While adopting HH did appear to both own and cultivate more land than non-adopters, there is no evidence that adopters were more equal with regard to these variables than non-adopting HH. Indeed, in terms of land cultivated in 2003, if anything, there was more uniformity in distribution amongst the non-adopter category (G = 0.37 compared with G = 0.416 for adopters).

A further possibility is that the greater uniformity amongst adopting HH in terms of cotton income has less to do with extent of land cultivation and more to do with income per unit of land. Only a sample of plots could be surveyed in detail for adopting and non-adopting HH and the results are shown as Table 4. In this table the plots are broken down into ‘Bt plots’ (of adopters), non-Bt plots (of adopters) and non-Bt plots (of non-adopters) over two growing seasons (2002 and 2003). Variables are yield, revenue, various costs (including labor) and gross margin (revenue – the costs listed here). The yield of Bt plots was significantly greater than for those of non-Bt plots of non-adopters ($P < 0.001$) and this resulted in a much higher revenue ($P < 0.001$). Costs per acre were also higher for Bt versus non-Bt of non-adopters ($P < 0.001$) and the main reason for this was the much higher cost of Bt seed. Fertilizer and total labor costs for the two groups were comparable. As would be expected, bollworm insecticide costs for Bt plots were significantly lower ($P < 0.05$) than non-Bt. Overall, gross margin of Bt plots was significantly higher ($P < 0.001$) than non-Bt of non-adopters, and hence provides a similar picture to that seen in much of the literature presented in Table 1.

Table 5. Production and cost statistics for 'Bunny' (non-Bt variety) and other non-Bt plots of adopters and non-adopters.

	Adopter 'Bunny' plots				Non-adopter plots of 'Bunny'				Other non-Bt plots			
	2002		2003		2002		2003		2002		2003	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Yield (quintles/acre)	5.3	2.31	7.15	5.77	4.6	3.04	5.82	3.3	4.21	2.17	3.98	1.89
Revenue (Rp/acre)	11,107	5,178	15,679	13,055	9,583	6,724	12,284	7,327	8,708	5,217	8,627	4,464
Costs (Rp/acre)												
Seed	457	139	475	83	392	105	415	146	446	112	444	171
Total fertilizer	1,098	929	814	601	796	479	917	748	961	663	1,417	2,835
Bollworm insecticide	390	373	711	1,171	457	554	338	329	573	480	584	875
Irrigation	96	225	66	59	43	65	52	88	40	108	63	132
Total labor	1,707	1,079	2,075	1,235	1,925	1,522	1,810	944	1,553	645	2,181	2,086
Total costs	**3,403**	**2,423**	**3,872**	**1,954**	**3,715**	**2,391**	**3,390**	**1,467**	**3,528**	**1,621**	**4,638**	**5,780**
Gross margin (Rp/acre)	7,704	5,351	11,807	12,904	5,868	6,986	8,894	7,063	5,179	4,665	3,989	6,472
Sample size	23		11		19		19		33		38	

Table 6. Gini coefficients based on gross margin (Rp/acre) for the three categories of respondents.

	Gini coefficient	Difference in Gini coefficient	Mean gross margin (Rp/acre)	Difference in gross margin (Rp/acre)
Non-Bt plots	0.63	-	4,542	-
Bunny plots	0.47	-0.16	8,160	3,618 (80% increase)
Bt plots	0.3	-0.17	13,397	5,237(64% increase)

But many Bt adopters grow both Bt and non-Bt cotton. The 'adopter' effect on yield can be illustrated by comparing non-Bt plots of adopters and those of non-adopters as shown in Table 4. While Bt plots have higher yields ($P < 0.001$), revenues ($P < 0.001$) and gross margins ($P < 0.05$) compared to the non-Bt plots of adopters, yield and revenue are also significantly higher for non-Bt plots of adopters relative to those of non-adopters. Thus, the results suggest that Bt farmers can generate higher yields and revenues on a per acre basis from non-Bt cotton, but what is the reason for this? Interestingly, there are differences in terms of the non-Bt varieties grown by adopters compared to those of non-adopters, and the variety 'Bunny' is especially popular amongst Bt adopters. Some 71% of the non-Bt plots of adopters were planted to Bunny, while the comparable figure for non-adopters was only 40%. Bunny performs well in this part of India, as evidenced by data in Table 5, which compares Bunny to other non-Bt varieties of adopters and non-adopters. Bunny has a significantly greater yield ($P < 0.01$) and revenue ($P < 0.05$) than other non-Bt types and generally does not appear to require as much expenditure on bollworm insecticide. Overall, the gross margin of Bunny is higher than other non-Bt varieties, although this difference is not statistically significant ($P > 0.05$). It would appear that Bt adopters and Bt non-adopters have similar yields, revenues and inputs for Bunny. Thus, a significant part of the 'Bt adopter' effect seen in non-Bt plots is likely due to their preferential planting of Bunny.

How does this impact the issue of equality? The values of G for gross margin/acre of plots of Bt cotton, Bunny and other non-Bt cultivars are shown in Table 6 and it's here that an explanation for the total cotton income results begin to emerge. Inequality is less (lower value of G) for plots of Bt (0.3) than for Bunny (0.47) and non-Bt plots (0.63). When G is compared to average gross margin/acre then the two variables are related such that as average gross margin increases then G declines. Adopters of Bt cotton increase their gross margin per acre compared to non-adopters, and this gap is wider than for Bunny. However, adopters are also more uniform in terms of gross margin/acre. This relative equality amongst plots of Bt and Bunny non-Bt cotton favored by adopters would then be expected to feed through into the greater equality amongst Bt-adopting HH compared to non-adopters in terms of their total cotton income.

Discussion

A simple comparison of Bt plots of adopters against non-Bt plots of non-adopters suggests that the Bt plots outperform non-Bt in a number of regards. Using gross margin per acre as the basis for comparison, it is apparent that Bt plots have 2.5 times the gross margin of non-Bt plots of non-adopters in both seasons. These results are comparable to those found from a range of studies based in India (Bennett et al., 2004, 2005; Morse et al., 2005a) and elsewhere (Qaim & De Janvry 2005; Yang et al., 2005a). While there is no evidence from these data that early adopters are older or more experienced than non-adopters, this cannot be ruled out and there were differences in assets such as land area. Most important of all it would appear that adopters of Bt tend to grow well-performing non-Bt varieties of cotton such as Bunny. If only the Bt and non-Bt plots of adopters are considered then the gross margin advantage of Bt plots reduces to 1.6 times that of non-Bt plots over both seasons. Therefore, as critics would charge, there is evidence of a 'farmer' effect in the reported yield advantage of growing Bt cotton, at least in the early years of adoption. However, it should be noted that even a yield advantage of 1.6 times for Bt over a high performing non-Bt variety is still a significant benefit for resource-poor farmers and could explain the popularity of Bt in Maharashtra.

The *increased inequality* argument put forward by critics of Bt cotton needs to be looked at in two ways, and it is important to remember that for these farmers, cotton income accounted for 85 to 88% of total HH income in 2003. Thus cotton income is by no means a marginal concern for these HH. Adopting Bt actually enhances equality within the adopter group, but this group was also preferentially adopting better-performing non-Bt varieties (such as Bunny) as well. Secondly, there is a widening gap in gross margin per acre between adopters of Bt and non-adopters. An increased gross margin from growing Bt relative to both Bunny and other non-Bt varieties would support the contention of greater inequality between farmers who can adopt Bt and those who cannot, for whatever reason, adopt. But the same argument would apply to adopters of Bunny. The difference is that with Bt the effect is greater. However, the values of G based on gross margin show that adopting Bunny and Bt cotton reduces inequality within the plots of adopter groups relative to that for other non-Bt cotton plots. Plots of Bt and Bunny are more uniform, at least in terms of gross margin/acre. The non-Bt group of plots (excluding Bunny) comprise a wide range of varieties, and could conceivably also encompass a wider range of farmer skill. Maybe Bt adopters are more uniform in their skill base, but it is more likely that these high-performing varieties are reducing one of the key constraints to cotton production – bollworm – that is probably a key driver of heterogeneity. Without Bt, cotton farmers are entirely reliant on insecticides, with all of the accompanying and complex decisions over which insecticides to use, when to apply, how much to use and how to apply.

Conclusion

The decision of what comparison to make is of critical importance in GM crop research. This is also true for the argument surrounding an increase in inequality with introduction of a GM variety such as Bt cotton. The results presented here suggest that a claim of an increase in gross margin of Bt cotton relative to non-Bt can be either 2.5 or 1.6 times. Both are equally true. The difference, of course, rests with the meaning of the term 'non-Bt.' But with Bt cotton, and it is to be suspected with GM crops as a whole, inequality has to be seen both *within* groups (Bt reduces inequality) and *between* groups (Bt increases inequality). Critics of GM crops have tended to focus solely on the latter without considering the former. If the complexity of having to apply insecticide to a crop where insect pests are a major, if not *the* major, constraint generates heterogeneity then ironically the wider adoption of Bt cotton may act to reduce inequality. For those engaged in agricultural development it all comes down to what is the desired outcome.

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