

## Comparing the Performance of Official and Unofficial Genetically Modified Cotton in India

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Genetically modified (GM) cotton was approved for commercial cultivation in 2002. Hybrids to date have carried the Bt (*Bacillus thuringiensis*) gene, which confers resistance to Lepidoptera and certain Coleoptera. As well as "official" Bt hybrids (i.e., those that have gone through a formal approval process), there are "unofficial" Bt hybrids produced without such approval. The owners of the official hybrids, Monsanto-Mahyco, claim that the unofficial hybrids are not as good and could even damage the perception of Bt cotton amongst farmers. Anti-GM groups claim that neither type of Bt hybrid provides either yield or economic advantages over non-Bt hybrids. This paper reports the first study of official versus unofficial versus non-Bt hybrids in India (622 farmers in Gujarat State) with the specific aim of comparing one hypothesized ranking in terms of gross margin of (a) official Bt hybrids, (b) unofficial Bt hybrids, and (c) non-Bt hybrids. Results suggest that the official Bt varieties (MECH 12 and MECH 162) significantly outperform the unofficial varieties in terms of gross margin. However, unofficial, locally produced Bt hybrids can also perform significantly better than non-Bt hybrids, although second-generation (F2) Bt seed appears to have no yield advantage compared to non-Bt hybrids but can save on insecticide use. The paper explores some of the implications of this ranking.

**Key words:** Bt cotton, GM crops, Gujarat, India

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### Introduction

The Indian Government permitted commercial cultivation of genetically modified Bt (*Bacillus thuringiensis*) cotton in March 2002 (Raghuram, 2002). Bt cotton is genetically engineered for resistance to Coleoptera and certain Lepidoptera, such as the old world bollworm (*Helicoverpa armigera*), pink bollworm (*Pectinophora gossypiella*), spotted bollworm (*Earias vittella*), and spiny bollworm (*Earias insulana*), and therefore should reduce the use of toxic, environmentally damaging, and expensive insecticide. Although this may sound like a laudable objective, there has in fact been considerable debate and conflicting views regarding the release of Bt cotton. Criticism has centered largely on whether the Bt hybrids confer any significant yield or economic advantage, let alone whether the pesticide load into the environment is reduced (Friends of the Earth International, 2004). Indeed, it has been argued that Bt cotton adopters are actually worse off relative to non-Bt cotton growers (Shiva & Jafri, 2003).

Despite this debate over performance (economic, environmental, agronomic, or otherwise), there is no doubt that the hybrids with the Bt-based resistance have proved to be popular. The true extent of the popularity of Bt cotton has yet to be determined and could be patchy, but estimates suggest that in the 2002/03 and

2003/04 seasons there were 29,415 and 86,240 ha of Bt cotton, respectively, and in 2004/05, this is likely to rise to as much as 530,800 ha. One interesting indicator with regard to popularity is the rise of "unofficial" Bt cotton varieties produced by local Indian companies:

Indian agricultural minister Sharad Pawar admitted in parliament on August 16 that there is a flourishing illegal market in genetically modified (GM) cotton seeds, strengthening allegations by the industry that more than half of all the GM cotton now growing in the country is from unapproved varieties. (Jayaraman, 2004, p. 1333)

The official varieties (i.e., those with government sanction) are owned by Monsanto and its Indian partner, Mahyco, based in Mumbai (Bombay). These companies have invested heavily in field trials and are understandably concerned about the release of unofficial hybrids, partly because of the obvious loss in profit but also because they fear that the unofficial hybrids will perform relatively badly and thereby give GM cotton a bad name. On the other hand, the unofficial varieties would seem to be advantageous, in that they provide the technology at a cheaper price to small-scale farmers. Given

**Table 1. Possible gross-margin rankings of Bt types.**

Rank	Monsanto-Mahyco	Alternative	Anti-GM
1	Official Bt	Unofficial Bt	Non-Bt
2	Unofficial Bt	Official Bt	Unofficial/official Bt
3	Non-Bt	Non-Bt	

the substantial premium on official GM seed, the cheaper unofficial hybrids could help with profitability. However, anti-GM groups are concerned about the potential for cross-contamination of crops that could be exacerbated by the widespread growing of unofficial varieties (Greenpeace, 2004).

Given these divergent views, there are a number of possible rankings in terms of gross margin that could be postulated. Three examples are shown in Table 1. The first model corresponds to the Monsanto-Mahyco vision, where both types of Bt confer resistance and hence save on insecticide costs. The difference is that the official hybrids perform better than the unofficial ones because of better breeding and more extensive testing. Hence, the companies would argue, yield and revenue should be higher. The second, “alternative” model assumes that the unofficial hybrids are cheaper for farmers to purchase than the official types and hence have better gross margins (assuming that all other costs and revenue are about the same). The third model is an anti-GM position, where Bt does not reduce insecticide costs in any significant way, but seed costs are higher. Hence, the non-Bt hybrids should have the best gross margin.

Which of these three scenarios is correct? This question forms the basis of the research reported here. The data are from a survey of 622 cotton growers residing in Gujarat State, which produces some 32% of India’s cotton output (Singh, 2004). The value of this research is that it records economic performance of the official and unofficial Bt cotton varieties under real commercial field conditions rather than trial plot data (Naik, 2001; Qaim & Zilberman, 2001) and as such is the first such study of its kind in India. The study focused on two official Bt hybrids—MECH 12 and MECH 162, released by Mahyco-Monsanto—and an unofficial Bt hybrid referred to here as *F1* (first-generation seed after crossing two inbred lines). During the survey, a second form of unofficial hybrid was encountered: saved seed from *F1*. This second type, referred to as *F2*, should have reduced hybrid vigor due to inbreeding amongst *F1* plants. The final type is referred to here as *non-Bt* but in fact covers a number of different hybrids. There are two species of cotton grown in Gujarat, *G. hirsutum* and *G. arboreum*; most of the non-Bt types are an intra-*hirsu-*

*tum* hybrid, with the remainder being planted to improved (nonhybrid) *hirsutum* and *arboreum* cultivars. Popular non-Bt varieties include Bunny, Tulsi, NHH-44, and JK-666.

## Methodology

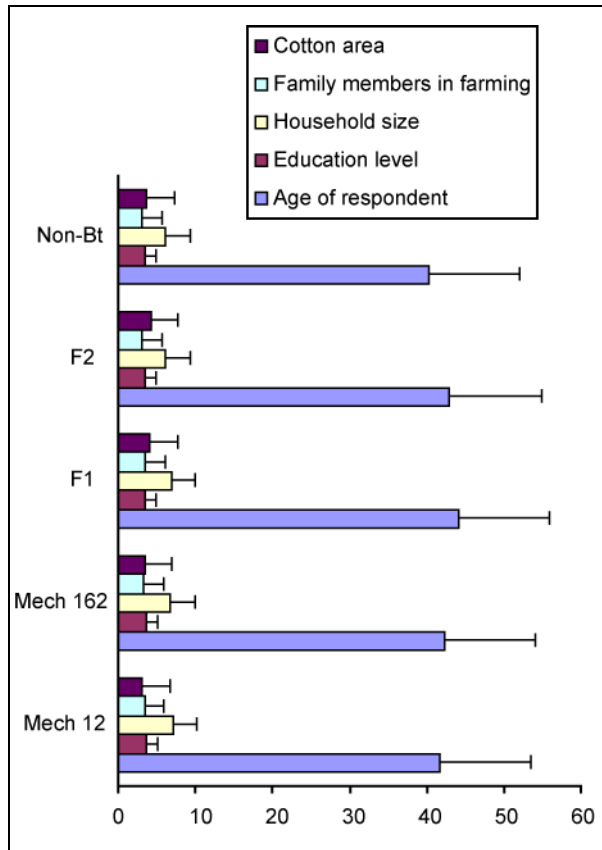
A questionnaire-based survey of cotton farmers in Gujarat was undertaken during December 2003 and January 2004. Respondents were randomly sampled from a list (provided by seed suppliers) of farmers growing cotton across six districts of Gujarat. The questionnaire was designed to collect information on cotton cultivation practices (e.g., cotton varieties planted, cotton yields, output prices, and use of inputs such as seed, fertilizer, sprays, and labor). The survey also included questions regarding the education level of the farmer and the number of household members engaged in cotton production. These questions were included to test the possibility that more experienced and knowledgeable farmers, or those with more available labor, would adopt Bt first. Hence, a difference in yield between Bt and non-Bt cotton could be attributed to better management rather than genotype.

After rejecting incomplete forms, a total of 622 farmers were included in the analysis. Of these, 618 grew only one plot (field) of cotton planted to a single variety; the remaining four respondents had separate plots of both Bt (official or unofficial) and non-Bt cotton. Therefore, the total number of cotton plots included in the analysis was 626, and given the random nature of the sampling process, this broke down as follows:

- 306 plots were planted to official hybrids (MECH 12 and MECH 162);
- 169 plots were planted to unofficial hybrids (*F1* and *F2*); and
- 151 plots were planted to non-Bt cotton.

Data were coded where necessary before analysis. For example, education level was coded from 1 (*no education*) to 7 (*tertiary-level education*).

The use of cotton inputs by farmers was expressed in terms of expenditures on the main input categories—seed, manure, inorganic fertilizer, insecticide (for bollworm, sucking pests, and others), irrigation, and labor (for spraying and harvest). Using expenditure rather than quantities does have advantages, given that there are many different types of inorganic fertilizer and pesticide. The seed category is a function of differential cost of the varieties (e.g., it is well known that Bt hybrids cost more than non-Bt) and seed rate (quantity of seed used per area).

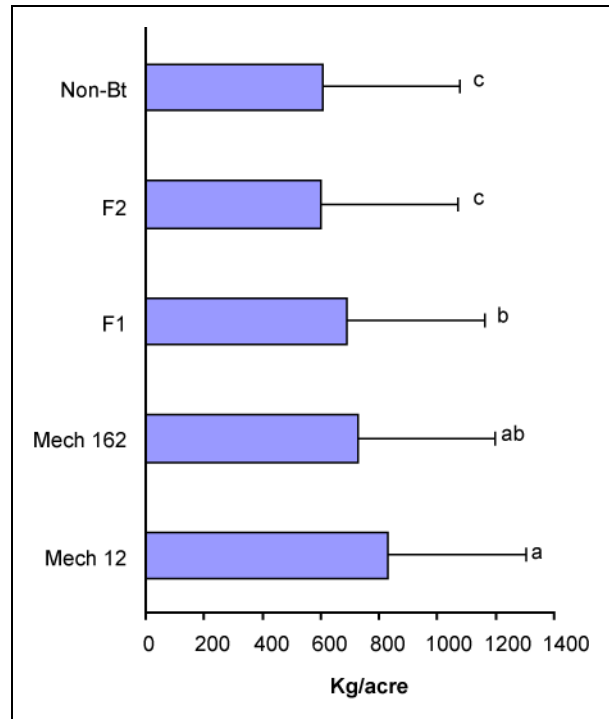


**Figure 1. Characteristics of the farmers growing the five cotton hybrids.**  
 Note. Bars are mean values; error bars represent one standard deviation.

Analysis was done with SPSS (Statistical Package for Social Systems) using the General Linear Model approach to analysis of variance; mean separation was determined via Duncan's Multiple Range test (DMR; significance tested at the 5% level of probability).

**Results**

The averages, standard deviations, and results of the DMR test (using letters to denote significant differences) are shown in Figures 1 to 6. With regard to the socioeconomic indicators of farmers and households (age of respondent, education level, household size, number of household members involved in farming, and cotton plot area) there were no significant differences between plots of the five hybrids (Figure 1). From these data, there is no evidence that older (more experienced) farmers, more educated farmers, or farmers with larger plots of cotton or with more labor available for farming, were overrepresented in the Bt categories. However, the evidence cannot be said to be conclusive, and the possi-

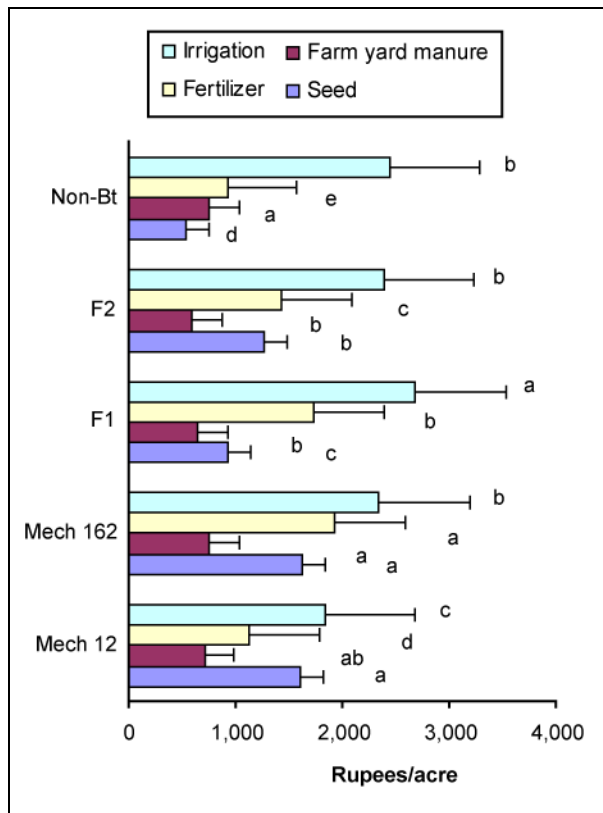


**Figure 2. Yields of the five cotton hybrids.**  
 Note. Bars are mean values; error bars represent one standard deviation. Mean separation was via Duncan's Multiple Range Test. Means with a common letter are not significantly different at the 5% level.

bility that the Bt plots were associated with farmers having more skill should be borne in mind when interpreting the results.

Cotton yield was highly variable, represented by the large standard deviation bars in Figure 2. The highest yields were recorded for the MECH varieties, followed by the F1 of the unofficial Bt. Increases in yield relative to non-Bt varied from zero (F2), 14% (F1), 20% (MECH 162), and 37% (MECH 12). This would appear to be broadly in line with the Monsanto-Mahyco model.

The costs incurred in production are shown in Figures 3 (nonpesticide inputs), 4 (pesticide inputs), and 5 (labor). Unsurprisingly, per-acre seed costs are highest for the MECH Bt varieties, due to the relatively high cost of the seed, whereas non-Bt is the cheapest (Figure 3). Seed costs for the F2 seed are relatively high even when compared to the F1 hybrids. With irrigation and fertilizer the picture is more complex, with no clear pattern between Bt and non-Bt emerging (Figure 3). Inorganic fertilizer costs are highest for farmers growing the MECH 162 seed and lowest for the conventional varieties, while irrigation costs are highest for the F1 hybrids,

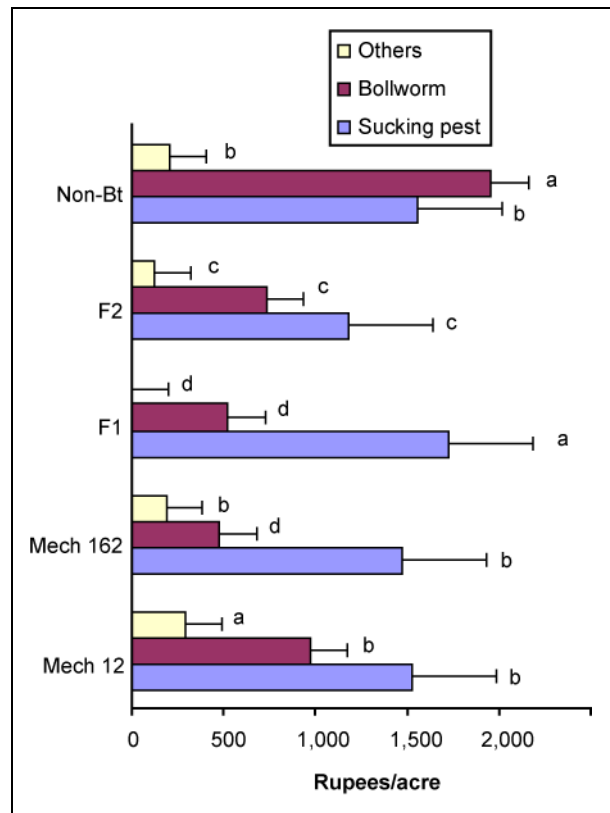


**Figure 3. Costs of some inputs (excluding insecticide and labor) for the five cotton hybrids.**  
 Note. Bars are mean values; error bars represent one standard deviation. Mean separation was via Duncan's Multiple Range Test. Means with a common letter are not significantly different at the 5% level.

lowest for MECH 12, and at a similar level for the remainder.

With regard to insecticides (Figure 4), the use and costs of bollworm spray is highest for the conventional varieties and much lower for all the Bt varieties, particularly the official MECH 162 variety (followed by the unofficial F1 hybrids). This is in line with the hypothesis that the Bt gene confers resistance and therefore less bollworm insecticide should be required. The cost of sucking pest sprays is highest for the F1 hybrids and lowest for the F2 seed. The third category of insecticide in Figure 4 is referred to as "others" and largely comprises seed dressings and leaf-eating pests (grasshoppers, etc.). These costs are the lowest for each of the five hybrids; it is difficult to extract a pattern.

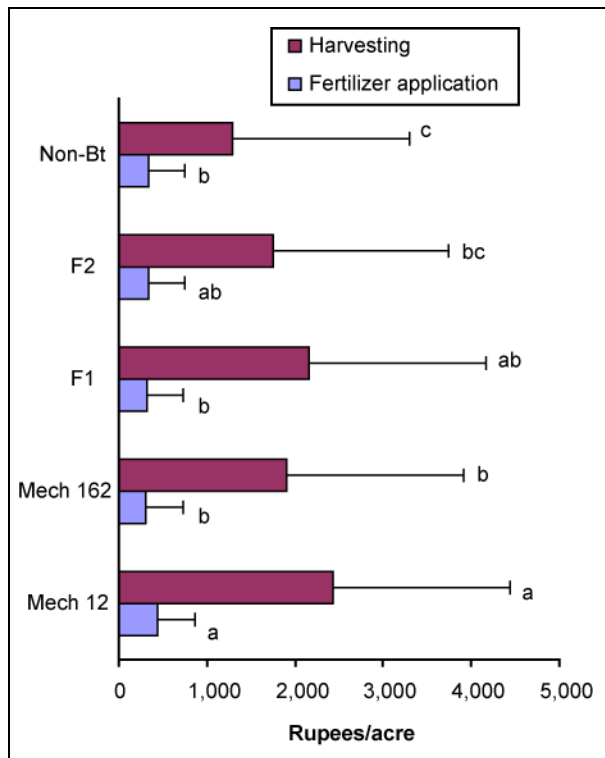
The labor costs for applying fertilizer and harvesting are shown in Figure 5. Again, there is much variation in the data. Higher yields of the Bt varieties unsurprisingly results in higher harvesting costs for those varieties.



**Figure 4. Costs of insecticide for the five cotton hybrids.**  
 Note. Bars are mean values; error bars represent one standard deviation. Mean separation was via Duncan's Multiple Range Test. Means with a common letter are not significantly different at the 5% level.

Costs of fertilizer application are broadly the same across all five hybrids.

Total costs (sum of costs in Figures 3, 4, and 5), revenue (yield × price), and gross margin (revenue – costs) are shown in Figure 6. Note that in this study, a record was kept of price obtained by each farmer, and the price of cotton is higher for the Bt varieties compared with the non-Bt, perhaps reflecting a better quality of cotton and less staining caused by bollworm. Therefore, a higher yield combined with a higher price generates significantly higher revenue for the Bt varieties (especially MECH) compared to non-Bt. Indeed, the ranking of revenue is that predicted in the hypothesis: MECH 12 – MECH 162 – F1 – F2 – non-Bt. Balanced against this is the fact that the MECH varieties have the highest per-acre costs, followed by F1 hybrid, non-Bt, and F2. Reduced expenditure on insecticide is more than offset by the greater cost of seed for the official Bt hybrids. This evidence suggests that the Bt technology is not cost reducing. However, in terms of gross margin, it is clear

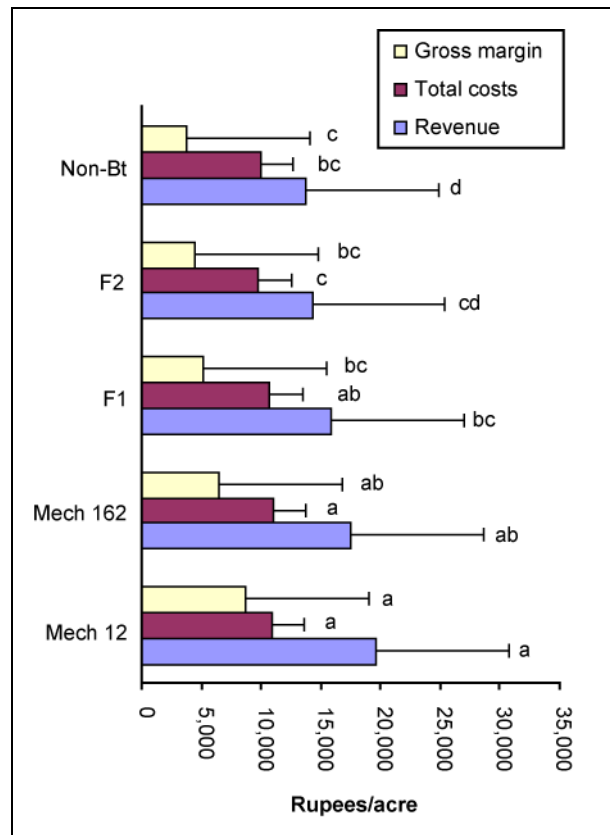


**Figure 5. Labor costs for the five cotton hybrids.**  
 Note. Bars are mean values; error bars represent one standard deviation. Mean separation was via Duncan's Multiple Range Test. Means with a common letter are not significantly different at the 5% level.

that this variable is considerably greater for MECH 12 followed by MECH 162. Indeed, the gross margin of MECH 12 was 132% that of the non-Bt varieties. This sizable difference is largely a function of increased revenue for the MECH hybrids. The F1 hybrids are the next-best performers in terms of gross margin, followed by F2 seed. All of the Bt varieties appear to outperform the conventional varieties—even the F2 seed, where per-acre yields are no better than conventional.

### Discussion

The results would appear to support the Monsanto-Mahyco ranking of hybrids rather than the alternative ranking or that of the anti-GM lobby. Although the unofficial Bt varieties generally outperform the non-Bt hybrids, they do not do as well as the official Bt cotton crops. The advantage of, and indeed main incentive to use, the unofficial Bt varieties for farmers is that the cost of seed for these varieties is lower than that for the seed of the official Bt varieties. The poor performance of the F2 compared to F1 was expected, but it is interesting to note that F2 has a higher gross margin than the non-Bt



**Figure 6. Total costs, revenue and gross margin for the five cotton hybrids.**  
 Note. Bars are mean values; error bars represent one standard deviation. Mean separation was via Duncan's Multiple Range Test. Means with a common letter are not significantly different at the 5% level.

varieties. Therefore, the evidence suggests that the extra investment in the MECH hybrids relative to the unofficial types does provide additional benefits for the farmer.

However, some issues need to be considered. First, it is important to remember that the research reported here relates to just one state (Gujarat is the main state to date that has seen substantial documented plantings of unofficial Bt cotton varieties) and one growing season in India. Regional variation would be expected.

Care also needs to be taken in terms of the farmer characteristics. Although some farmer/household characteristics are presented in Figure 1, it is well established that better farmers or those with access to better resources (soil, labor, etc.) tend to be more willing to try new technologies. Hence, some of the differences in Tables 2 to 6 could be the result of better management, rather than just different genotype. Because most of the farmers in the survey had a single plot of cotton planted

to a single hybrid, it was not possible to adjust for this management effect. Therefore, although the rank order of the hybrids in terms of gross margin is certainly suggestive of the Monsanto-Mahyco model, it cannot be said to be conclusive proof.

Thirdly, although the results provide little indication as to how stable this ranking would be in the future, it is possible to identify the factors that could have the greatest impact. The Indian government has claimed it is concerned about the use of unauthorized Bt cotton varieties, although at the same time little effort seems to have been made to close down production (AgraFood Biotech, 2004; Jayaraman, 2001, 2004). The issue is likely to intensify in the coming years, as up to 12 more official Bt cotton hybrids are set for release by Raasi Seeds, Ankur Seeds, and Mahyco (Jayaraman, 2004). If unofficial Bt cotton planting continues despite pressure from official seed suppliers, could these companies reduce the cost of their seed to make them more attractive to farmers? Ironically, even if seed costs of the unofficial hybrids are reduced to the same level of the non-Bt (~500 rupees/acre), or even handed out free of charge, the producers' gross margin would still not be as high as that obtainable from the official hybrids, simply because the advantage of the latter arises through the yield gain. Only if the unofficial Bt seed begins to match the official hybrids in terms of yield would farmers see an equal benefit from either type; however, this requires expensive investment.

What about the economic sustainability of production? It is, of course, impossible to draw many hard conclusions from just one year of data. However, one very simple way of exploring this issue is to present the production costs for the following season as a percentage of the gross margin for the current season and assume that any shortfall has to be covered by savings or credit. Table 2 shows the average costs of seed and all inputs per acre as a percentage of gross margin per acre.

Farmers adopting the Bt hybrids would have to spend a higher proportion of their gross margin to purchase seed (assumed to be the first input to be purchased) for the following season than nonadopters. However, total costs (as a percentage of gross margin) are much higher for the non-Bt hybrids (266%) compared to MECH 12 (126%), suggesting that farmers may not have to take so much cash from other sources to sustain production of the latter than the former. Of course, this says nothing about the biological sustainability of the single-gene-based Bt resistance or even the impact of official/unofficial Bt cotton hybrids on the sustain-

**Table 2. Average cost of seed and total costs as a percentage of per-acre gross margin.**

	MECH 12	MECH 162	F1	F2	Non-Bt
<b>Seed as % of gross margin</b>	18	25	18	28	14
<b>Total costs as % of gross margin</b>	126	169	209	218	266

ability of peoples' livelihoods in such complex socio-economic contexts as those of India. These issues require further research.

### Acknowledgments

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