AgBioForum, 7(3): 96-100. ©2004 AgBioForum.

Economic Impact of Genetically Modified Cotton in India

R.M. Bennett, Y. Ismael, U. Kambhampati, and S. Morse
University of Reading, Berkshire, UK

This paper presents the results of a study aimed at measuring the economic impact of genetically modified cotton in Maharashtra State, India. It is the first study of its kind in India in that the data have been collected from farmers growing the crop under market conditions, rather than from trials. The research compares the performance of more than 9,000 Bt and non-Bt cotton farm plots in Maharashtra over the 2002 and 2003 growing seasons. Results show that Bt cotton varieties have had a significant positive impact on average yields and on the economic performance of cotton growers.

Key words: Bt, cotton, economic impact, India, Maharashtra

Introduction

India is an important grower of cotton on a global scale. It ranks third in global cotton production after the United States and China; with 8–9 million hectares grown each year, India accounts for approximately 25% of the world's total cotton area and 16% of global cotton production. Most of the cotton in India is grown under rainfed conditions, and about a third is grown under irrigation (Sundaram, Basu, Krishna Iyer, Narayanan, & Rajendran, 1999). However, yields of cotton in India are low, with an average yield of 300 kg/ha compared to the world average of 580 kg/ha.

Cotton is a very important cash crop for Indian farmers and contributes around 30% to the gross domestic product of Indian agriculture. However, as with many cotton growing areas of the world, a major limiting factor is damage due to insect pests, especially the bollworm complex (American bollworm, *Helicoverpa armigera*; Spotted bollworm, *Earias vittella*; Pink bollworm, *Pectinophora gossipiella*). Sucking pests such as aphids (*Aphis gossypii*), jassids (*Amrasca bigutulla*), and whiteflies (*Bemisia tabaci*) are also a problem in terms of direct damage to the plant and the transmission of viruses.

In March 2002, the Indian government permitted commercial cultivation of genetically modified Bt (*Bacillus thuringiensis*) cotton. The Bt gene produces a protein that is toxic to bollworms. Bt cotton has now been produced in India for two seasons—2002 and 2003. In 2002, some 38,000 hectares were planted with Bt cotton, with more than 12,000 hectares being grown by more than 17,000 farmers in the state of Maharashtra. Given the scale of the cotton industry in India and the current global debates over advantages/disadvantages of GM technology, it is not surprising that there has been considerable and vigorous debate regarding the agronomic and economic performance of Bt cotton in India with various reports claiming both successes and failures. Qaim (2003), for example, analyzed trial data from seed companies testing Bt cotton and concluded that quantities of insecticide can be reduced by about one third relative to conventional (non-Bt) varieties, and yield gains can be up to 80% in seasons with bad bollworm infestations (a typical increase may be 30–40%). However, trial data can be criticized as being untypical models of the real conditions that prevail on Indian farms, and yield benefits may as a result be far less than those projected from trials. Even so, other studies have also shown potential gains to producers from growing Bt cotton in a number of developing countries (James, 2002), including South Africa (Bennett, Buthelezi, Ismael, & Morse, 2003; Ismael, Bennett, & Morse, 2002), Argentina (Qaim & De Janvry, 2002), Mexico (Traxler, Godoy-Avilla, Falck-Zepeda, & Espinoza-Arellano, 2001), Indonesia (Manwan & Subagyo, 2002), China (Pray, Rozelle, Huang, & Wang, 2002), and India (Naik, 2001; Qaim & Zilberman, 2003).

This paper presents an analysis of data collected from a large sample of farmers growing both conventional and Bt cotton under real commercial field conditions over two seasons (2002 and 2003) since Bt cotton has been licensed for commercial use in India; this is the first such study of its kind. The paper presents a much-needed and timely assessment of the performance of Bt cotton under typical farmer-managed conditions in India (Food and Agriculture Organization of the United Nations, 2004). Unlike previous Indian studies (Naik, 2001; Qaim & Zilberman, 2003; Qaim, 2003), it analyzes commercial field data rather than trial plot data. In this, it meets the recent (May 2004) FAO call for more market-based studies that will accurately reflect the agronomic and economic environments faced by growers of Bt cotton. The analysis concentrates on addressing the question as to whether Indian farmers have experienced economic gains from growing Bt hybrids released by a company affiliated with Monsanto (Mahyco-Monsanto) compared to a complex of non-Bt hybrids and cultivars. The paper explores the performance of the Bt variety, including spatial differences.

Methodology

The data were collected from two random samples of Bt cotton growers in the state of Maharashtra over two seasons (2002 and 2003). Maharashtra has an area of 307,690 km^2 and a population of almost 79 million; the state contributes some 23% of the nation's industrial output. It is among the most industrialized states in India, but even so about 70% of the state's population depends on agriculture. In the first season of the study a sample size of 2,709 farmers was obtained, whereas in the second season a sample size of 787 farmers was obtained. The samples covered 16 districts (out of 31 in the state) and 1,275 villages in three cotton-growing subregions of the state (Khandesh, Marathwada, Vidarbha).

There are two species of cotton grown in Maharashtra: *G. hirsutum* and *G. arboreum*. Most of the cotton grown (73% of cotton area) is an intra-*hirsutum* hybrid, with the remainder of the cotton area planted with improved (nonhybrid) *hirsutum* and *arboreum* cultivars. There are three Mahyco-Monsanto Bt cotton hybrids grown in the subregions: MECH-162 Bt, MECH-184 Bt, and MECH-12 Bt. Popular non-Bt varieties include Bunny, Tulsi, NHH-44, and JK-666.

Respondents were randomly selected within the three subregions. A questionnaire was designed and taken onto farms by trained and experienced agricultural extension workers. Farmers were personally interviewed, and data on cotton production (seed quantity/costs, number and cost of sprays, yields, cotton prices obtained, etc.) were collected. In the 2002 season (but not in 2003) it was also possible to get information on the soil type of each plot (three categories) and the number of irrigations. In nearly all cases, farmers grew both Bt and conventional cotton varieties on the same farm, providing useful plot data for comparing the performance of Bt and non-Bt varieties for the same producer. This provides some control for a number of producer-related factors that might influence performance of the technology (such as entrepreneurial ability, age, experience and expertise in growing the crop, and access to other inputs such as credit and irrigation). The data provide comparison across some 7,751 plots in 2002 and 1,580 plots in 2003. Raw data failed the Anderson-Darling test for normality, even with transformation; therefore, data have been compared with the Kruskal-Wallis nonparametric test.

Results

The results (means for Bt and non-Bt for the two seasons) are shown in Figures 1 and 2. As sample sizes were large, the standard errors were small and would not be seen as bars on these graphs. Therefore, the significance levels have been indicated.

In both seasons the non-Bt plots were larger than the Bt plots. In 2002, non-Bt plots averaged 0.97 ha, 35% larger than the average Bt plot size of 0.63 ha. In 2003, the non-Bt and Bt average plot sizes were 1.12 ha and 0.96 ha respectively, a difference of 14%. Both differences were statistically significant. There was no significant difference in terms of soil type and the number of irrigations each plot received. The lower plot size for Bt adopters could be due to a variety of factors but is most likely a function of the higher seed cost for those varieties. More expensive seed results in farmers growing a smaller area of the variety, assuming that they maintain the same plant density. The results also suggest that farmers are not preferentially planting the Bt variety on better soil or using more irrigations.

Significant differences are seen in the use of insecticide between non-Bt and Bt plots (Figure 1). Over both seasons the number of sprays applied to control sucking pests (such as aphids and jassids) was similar for non-Bt and Bt adopters (Figure 1a), and costs for this input are also quite similar (Figure 1c). Bt resistance, of course, confers no resistance to sucking pests, so one would expect to see the same pattern for both groups of farmers. However, although not so apparent from Figure 1, there were subtle but statistically significant differences. In 2002, the Bt growers applied less insecticide to control sucking pests that non-Bt adopters, while in 2003 this was reversed. It may be that in the first season some farmers did not fully understand the nature of the new technology and reduced sucking pest spray input, believing that the Bt variety needed less of such sprays. Bad experiences in 2002 may have led to an upsurge in spraying against these pests by Bt adopters in 2003.

For bollworm insecticide the pattern is very clear and consistent. The use of bollworm sprays was much lower for Bt than for non-Bt plots (Figure 1b), with a corresponding reduction in expenditure per hectare (Figure 1d; 72% and 83% on average in 2002 and 2003

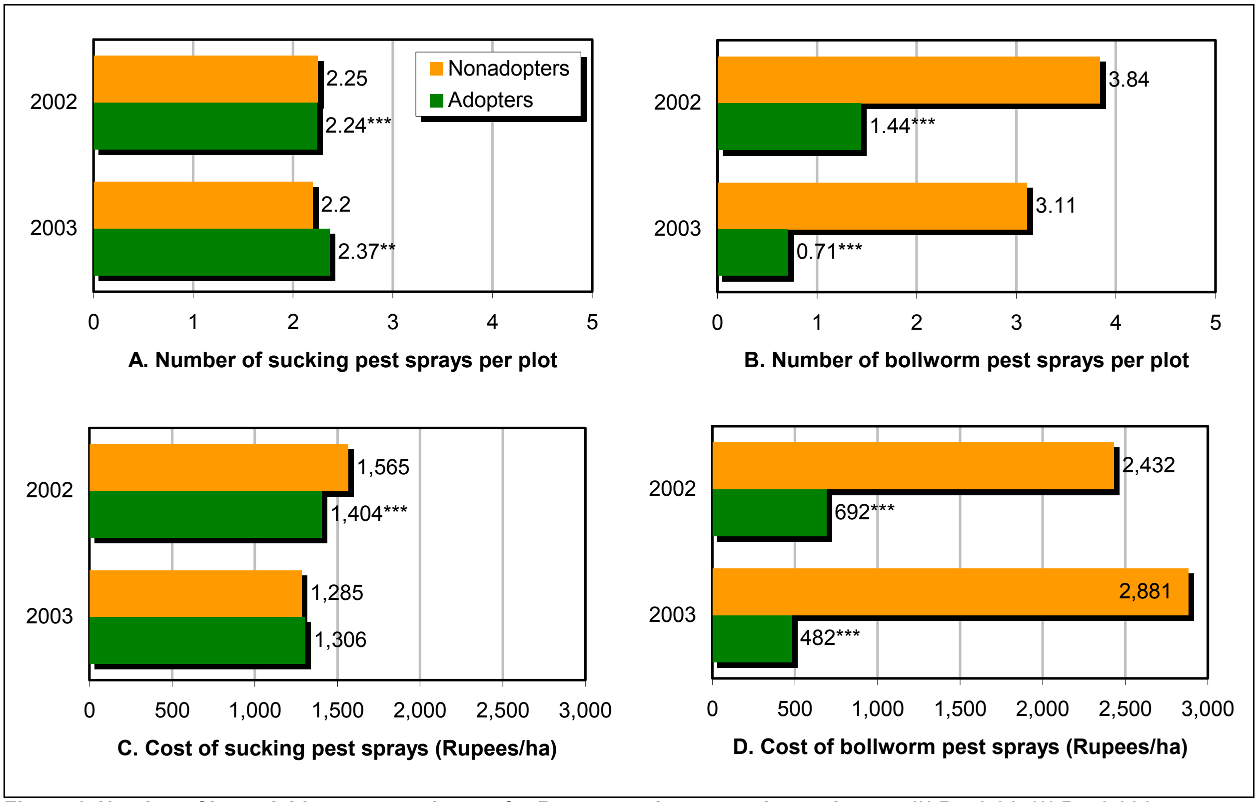

Figure 1. Number of insecticide sprays and costs for Bt cotton adopters and nonadopters (P < 0.01; *** P < 0.001; ns = not significant at 0.05).**

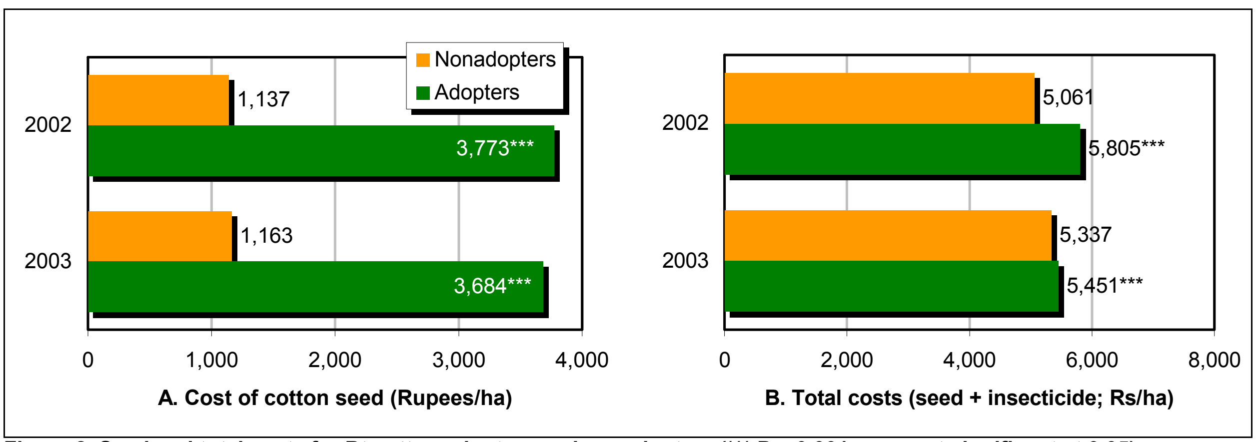

Figure 2. Seed and total costs for Bt cotton adopters and nonadopters (* P < 0.001; ns = not significant at 0.05).**

respectively). It should be noted that although Bt confers resistance to bollworm, some spraying may be necessary, as resistance diminishes with plant age. Therefore, even Bt adopters have to use some bollworm insecticide. Even so, Bt adopters made substantial savings.

However, savings on insecticide have to be balanced against the higher cost of Bt cotton seed. In Figure 2, the per-hectare seed costs were much higher for Bt adopters due to the premium they have to pay (Figure 2a; over 200% higher in both seasons). Indeed, once the higher seed costs are balanced against the savings in insecticide, the result showed slightly higher average costs overall for Bt adopters compared to nonadopters (Figure 2b; 15% and 2% in 2002 and 2003, respectively).

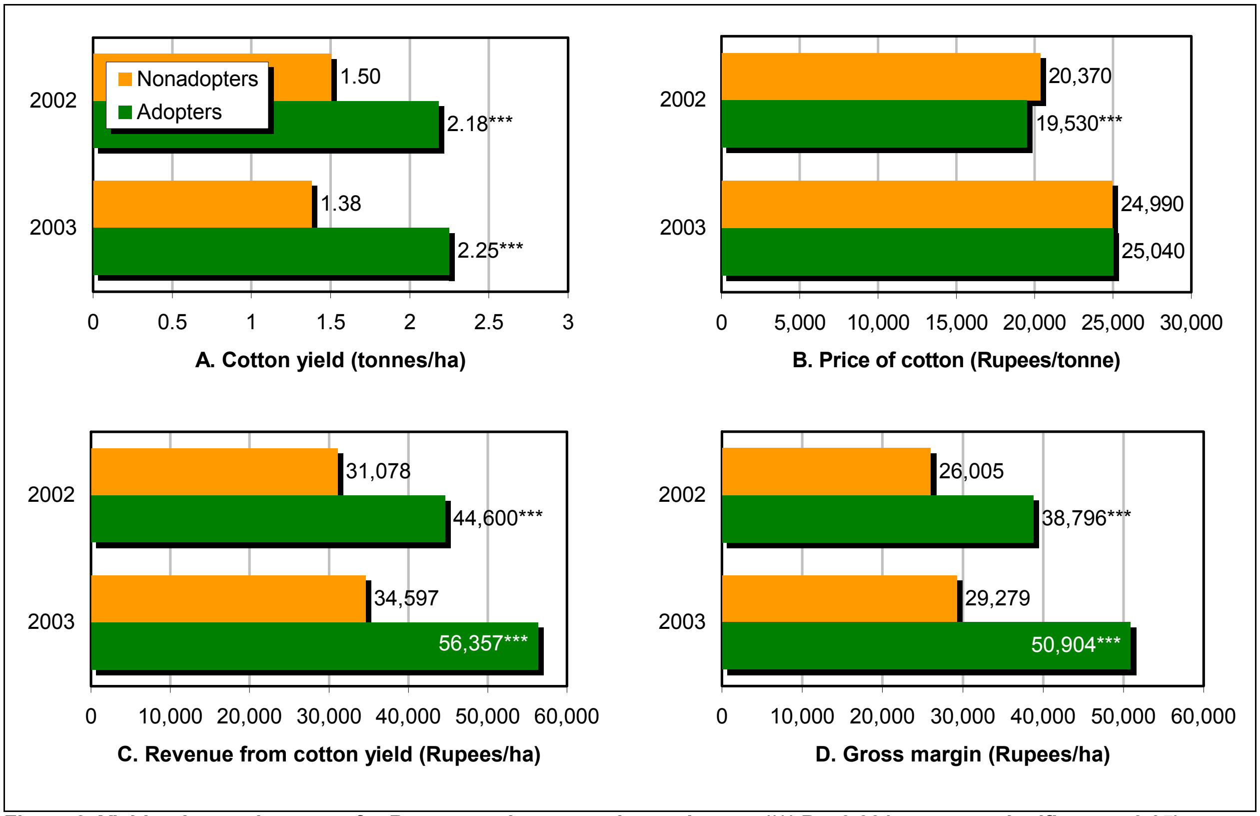

Figure 3. Yield, price, and revenue for Bt cotton adopters and nonadopters (* P < 0.001; ns = not significant at 0.05).**

Evidence suggest that the real benefits of growing Bt cotton are not so much in reduced costs but rather in higher output (Figure 3). Average yields for both types of cotton are high—typically 1.5–2.5 t/ha. This is a reflection of the good growing conditions for the crop and the use of irrigation. Yields of the Bt varieties are significantly higher than those of the non-Bt types (Figure 3a). In 2002, the average increase in yield for Bt over non-Bt was about 45%, while in 2003 this increased to 63%. These figures are of the order of magnitude found by Qaim (2003) with trial data and suggest a major benefit for the growers of Bt cotton compared to growers of non-Bt who use insecticide. Even though non-Bt growers are using a great deal of insecticide (3–4 sprays a season, on average), this might not be enough to control the pests. There may also be problems with ineffective and uneven application, as all spraying is done by hand. It should be noted that almost all of the cotton grown by farmers in the area is a hybrid, although it may be that the genetic background within which the Bt gene is located could also be providing some additional advantage.

Whatever the cause, higher yields for Bt cotton, combined with a price that is similar to non-Bt cotton (Figure 3b), results in much higher revenues for adopters of Bt cotton (Figure 3c). The price for Bt cotton was actually lower than the price for non-Bt cotton in 2002 (possibly as a result of unfamiliarity with the variety among merchants) but identical in 2003. When costs are taken into account (gross margin = revenue – variable costs), the result is a much higher gross margin for Bt growers compared to growers of non-Bt varieties (Figure 3d). It is worth noting that the average gross margin gap between Bt adopters and nonadopters was larger in 2003 (74%) than in 2002 (49%).

Discussion

This study is the first of its kind in India, in being based on real farms and markets rather than the more artificial conditions that exist with trials. Although trial data can be easily dismissed as being unrepresentative of the real conditions that farmers face, surveys such as this one are important in providing some insights into the market within which Indian cotton growers have to survive.

Findings appear to show that since its commercial release in 2002, Bt cotton has had a significant positive impact on yields and on the economic performance of cotton growers in Maharashtra. Yields of Bt cotton are significantly higher than those of non-Bt varieties, and use of insecticide is less—just as important, given insecticides' toxicity and potential for environmental damage. However, the higher profits are not due to reduced costs (i.e., less insecticide) but rather the higher revenue that arises from higher yield if the Bt variety is not disadvantaged in the market; although in 2002 there was some evidence of this, it was not present in 2003.

These findings echo the results from a number of other developing and developed countries (Baffes, 2004). However, it is important to note that although this research has looked at two seasons, it could be argued that there are no guarantees the gross margin benefits will continue. As with all market-led agricultural production, it is possible that prices for cotton will fall as supply increases, but costs may also come down. If the technology can sustain its apparent advantages to farmers in India, then there could be a significant positive impact on farmers' livelihoods and on agricultural gross domestic product for India.

References

Baffes, J. (2004). *Cotton: Market setting, trade policies, and issues.* Washington, DC: The World Bank Development Prospects Group.

Bennett, R., Buthelezi, T.J., Ismael, Y., & Morse, S. (2003). Bt cotton, pesticides labour and health: A case study of smallholder farmers in the Makhathini Flats, Republic of South Africa. *Outlook on Agriculture*, *32*(2), 123-128.

Food and Agriculture Organization of the United Nations. (2004). *The state of food and agriculture 2003-2004. Agricultural biotechnology: Meeting the needs of the poor?* Rome: FAO.

Ismael, Y., Bennett, R., & Morse, S. (2002). Farm-level economic impact of biotechnology: Smallholder Bt cotton farmers in South Africa. *Outlook on Agriculture*, *31*(2), 107-111.

James, C. (2002). *Global review of commercialised transgenic crops featuring Bt cotton* (ISAAA Brief No. 26). Ithaca, NY: International Service for the Acquisition of Agri-Biotech Applications.

Manwan, I., & Subagyo, T. (2002, July). *Transgenic cotton in Indonesia: Challenges and opportunities.* Paper presented at the regional workshop for the South East Asian Biotechnology Information Centers, Philippines.

Naik, G. (2001). *An analysis of socio-economic impact of Bt technology on indian cotton farmers.* Ahmedabad, India: Indian Institute of Management, Centre for Management in Agriculture.

Pray, C., Rozelle, S., Huang, J., & Wang, Q. (2002). Plant biotechnology in China. *Science*, *295*, 674-677.

Qaim, M. (2003). Bt cotton in India: Field trial results and economic projections. *World Development*, *31*(12), 2115-2127.

Qaim, M., & De Janvry, A. (2002, July). *Bt cotton in Argentina: Analysing adoption and farmers' willingness to pay.* Paper presented at the American Agricultural Economics Association, Long Beach, CA.

Qaim, M., & Zilberman, D. (2003). Yield effects of genetically modified crops in developing countries. *Science*, *299*, 900-902.

Sundaram, V., Basu, A.K., Krishna Iyer, K.R., Narayanan, S.S., & Rajendran, T. P. (1999). *Handbook of cotton in India*. Mumbai, India: Indian Society for Cotton Improvement.

Traxler, G., Godoy-Avilla, S., Falck-Zepeda, J., & Espinoza-Arellano, J.J. (2001, June). *Transgenic cotton in Mexico: Economic and environmental impacts.* Paper presented at the 5th International Conference on Biotechnology, Science and Modern Agriculture: A new industry at the dawn of the century, Ravello, Italy.