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Genetically modified insect resistance in cotton: some farm level economic impacts in India

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Abstract

The paper explores the impact of insect-resistant *Bacillus thuringiensis* (Bt) cotton on costs and returns over the first two seasons of its commercial release in three sub-regions of Maharashtra State, India. It is the first such research conducted in India based on farmers' own practices rather than trial plots. Data were collected for a total of 7793 cotton plots in 2002 and 1577 plots in 2003. Results suggest that while the cost of cotton seed was much higher for farmers growing Bt cotton relative to those growing non-Bt cotton, the costs of bollworm spray were much lower. While Bt plots had greater costs (seed plus insecticide) than non-Bt plots, the yields and revenue from Bt plots were much higher than those of non-Bt plots (some 39% and 63% higher in 2002 and 2003, respectively). Overall, the gross margins of Bt plots were some 43% (2002) and 73% (2003) higher than those of non-Bt plots, although there was some variation between the three sub-regions of the state. The results suggest that Bt cotton has provided substantial benefits for farmers in India over the 2 years, but there are questions as to whether these benefits are sustainable.

Keywords: India; Maharashtra; Bt cotton; Economic impact; Genetic modification

1. Introduction

The role of genetic modification (GM) for promoting agricultural sustainability is of interest to a wide range of groups, including farmers, consumers, researchers, environmental pressure groups and politicians. At one level GM can generate characteristics that should encourage sustainability, particularly the potential for enhanced crop resistance to pests promising substantial decreases in the use of toxic and environmentally damaging pesticide (a key consideration in almost all perspectives of agricultural sustainability). Yet views on the impact of GM have become increasingly polarised. Its proponents herald it as the technology for the future with promises that it will solve the problem of world hunger as it revolutionises agriculture, facilitates sustainability and improves food security and profitability (Nuffield Foundation, 1999; Lehmann, 2001; Nuffield Council on Bioethics, 2003). Yet it has also become the personification of the 'evils' of industrial agriculture with claims of potential environmental disruption and damage to human health [1].

The genetic modification of cotton (*Gossypium hirsutum*) for insect resistance to the bollworm complex (Lepidoptera) is being heralded as a highly beneficial application of agricultural GM technology. Of all crops, cotton is arguably the one most limited by insect attack. For the most part, cotton crop protection is based on the use of insecticide, mostly pyrethroid and organophosphorus-based products. Given that cotton receives

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[1]There are many examples of such claims, but the interested reader is referred to the Genewatch website http://www.genewatch.org/ for an excellent precise of anti-GM arguments. The website also provides an excellent set of links to anti-GM campaign groups.

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some 20% of all global insecticides applied each year (Mayer, 2003), with farmers having to apply insecticide up to 12 times a season, anything which reduces this toxic load on the environment (and indeed for people) would appear to be beneficial.

Genetic modification of insect resistance in cotton has been based on a number of related genes from the bacterium *Bacillus thuringiensis* (Bt) that code for proteins toxic to Lepidoptera and some Coleoptera. The most common form of the latter is the use of a gene that codes for the protein Cry1Ac. Many forms of this endotoxin exist (Gonzalez-Cabrera et al., 2003), and research is currently being undertaken to stack the gene for Cry1Ac with a second gene which codes for the related protein Cry2Ab. Such stacking is important as it is possible that pests could overcome the resistance presented by single genes, be it derived via GM or conventional breeding (Forrester, 1994; Riebe, 1999; Tabashnik et al., 2000). It should be noted that the use of the Bt endotoxin does not provide protection against other insect pests such as sap feeders (aphids and jassids). Also, the levels of endotoxin in the plant do decline with age so some spraying of insecticide against bollworm may be necessary in later stages of crop growth. Whether the Bt-based resistance can be sustained following large-scale commercial release is a question still awaiting an answer (Carriere et al., 2001).

Insect-resistant cotton based on the Bt gene has been commercially released in a number of countries, and results suggest that it is having a positive impact on yields, profits, the environment and human health (James, 2002). Countries where such studies have been conducted include South Africa (Bennett et al., 2003; Ismael et al., 2002), Argentina (Qaim and De Janvry, 2002), Mexico (Traxler et al., 2001), Indonesia (Manwan and Subagyo, 2002), China (Pray et al., 2002) and India (Naik, 2001; Qaim and Zilberman, 2003). For example, Qaim (2003) analysed trial data from India which tested Bt cotton alongside non-Bt (conventional) varieties and concluded that quantities of insecticide can be reduced by about one third relative to non-Bt varieties and yield gains can be up to 80% in seasons with bad bollworm attack (typical range may be between 30% and 40% increase).

The studies so far undertaken with Bt cotton in the developing world have been based either on trial data (Qaim and Zilberman, 2003) or data collected from farmer surveys (Ismael et al., 2002; Bennett et al., 2003). Trial data have the advantage of being collected under controlled conditions and are usually rich in terms of depth of information, but may be criticised as being 'unrepresentative' of real farm conditions. Survey data based on farmers' practices tend to be highly variable and more difficult to collect, but are at least more representative of the 'environment' (including economic and social aspects) under which farmers produce cotton (Food and Agriculture Organization of the United Nations (FAO), 2004). Country studies differ in their balance of trial and survey data. For example, to date the only evidence for economic impacts of growing Bt cotton in India has come from trial data (Naik, 2001; Qaim and Zilberman, 2003; Qaim, 2003). This paper aims to redress the balance by presenting an analysis of data collected from a large sample of farmers growing both conventional and Bt cotton under commercial field conditions over two seasons (2002 and 2003) since Bt cotton has been licensed for commercial use in India, and is the first such study of its kind for that country. In that regard it helps address the recent (May 2004) Food and Agriculture Organisation (FAO) call for more 'market-based studies'. 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 to Monsanto (Mahyco-Monsanto) compared to a complex of non-Bt hybrids and cultivars.

2. Cotton in India

India is an important grower of cotton on a global scale. It ranks third in global cotton production after USA and China, and with 8–9 million ha grown each year, 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 under irrigation (Sundaram et al., 1999). However, yields of cotton in India are low with an average yield of 300 kg/ha compared with a world average of 580 kg/ha, although yields can be higher under irrigation. Nevertheless, cotton is an important cash crop for Indian farmers and contributes around 30% to the gross domestic product of Indian agriculture.

Insect pests of cotton in India include a bollworm complex (American bollworm, *Helicoverpa armigera*; Spotted bollworm, *Earias vittella*; Pink bollworm, *Pectinophora gossipiella*) as well as sucking pests such as aphids (*Aphis gossypii*), jassids (*Amrasca bigutulla*) and whitefly (*Bemisia tabaci*). A wide range of insecticides are applied against these including profenofos, dichlorvos, indoxacarb, imidacloprid, quinolphos, monocrotophos, cypermethrin, triazophios, endosulfan, fenvalerate and thiamethoxam. Prices, availability and preferences regarding these insecticides vary widely across India.

In March 2002 the Indian Government permitted commercial cultivation of Bt cotton, and the country now has 3 years of experience with the crop. In 2002 some 38,000 ha were planted with Bt cotton, with over 12,000 ha of this being in the state of Maharashtra grown by over 17,000 farmers. All of the Bt cotton in