Bt Cotton Yields and Performance: Data and Methodological Issues
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further research and development in agricultural biotechnology, despite their political deployment for just this purpose.

NOTES

1 Mimeo tables and personal communication, October 2005; and conversations with D B Desai, Navbharat Seeds, June 2005.
2 See Roy (2006); Roy et al (2007); Ramaswami, Pray and Lalitha (2011).

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# Bt Cotton Yields and Performance

## Data and Methodological Issues

N CHANDRASEKHARA RAO

This article rebuts the argument that shortcomings in Bt cotton studies and divergence between yield gains and extent of adoption of Bt hybrids make it impossible to conclusively say anything about the impact of genetically modified seeds. Further, it points out that there have been numerous studies that have controlled for selection and cultivation bias, and concluded that Bt cotton has had statistically significant positive yield effects.

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Glenn Davis Stone in "Constructing Facts: Bt Cotton Narratives in India" (EPW, 22 September 2012) contends erroneously that the shortcomings in Bt cotton studies and divergence between yield gains from Bt hybrids make it impossible to conclusively say anything about its impact, and then goes on to explain the "interests" in popularising the "triumph narrative" of Bt. While Ronald Herring elsewhere in this issue reflects on the issue of "interests", the purpose of this article is to examine the controversy surrounding yield data and perceived shortcomings of the methodologies adopted. In doing so, I also address the question of whether the available evidence allows us to arrive at a definitive conclusion on this issue, crucial to any further application of biotechnology in Indian agriculture.

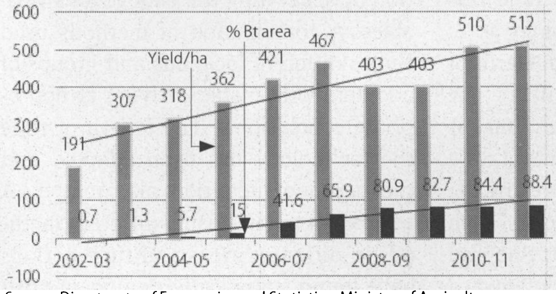
### Two Data Sets on Yield

The crux of Stone's yield arguments, citing K R Kranthi, was that the improvements in per hectare yields of cotton do not have anything to do with the percentage of adoption of Bt hybrids. However, this is not the true picture, an understanding of which requires a brief background about cotton data sets in India.

There are two sets of data on cotton area, production and productivity in the country brought out by the department of economics and statistics (DES) of the Ministry of Agriculture and the cotton advisory board (CAB) representing different trade bodies under the Ministry of Textiles. The DES is the nodal agency for all statistics related to agriculture in the country and has an elaborate mechanism for collecting information on the crop area. It conducts a large number of crop-cutting experiments (CCEs) to find out productivity and arrive at production figures. On the other hand, the CAB uses the area statistics given by DES and estimates the production based on a consensus arrived at on market arrivals and quantities of cotton pressed, in consultation with various stakeholders such as the Cotton Association of India, Confederation of Indian Textile Industry, Indian Cotton Mills Federation (ICMF), and the Directorate of Cotton Development. The CAB then calculates the per hectare yields based on its own estimated production and the area figures provided by the DES.[1]

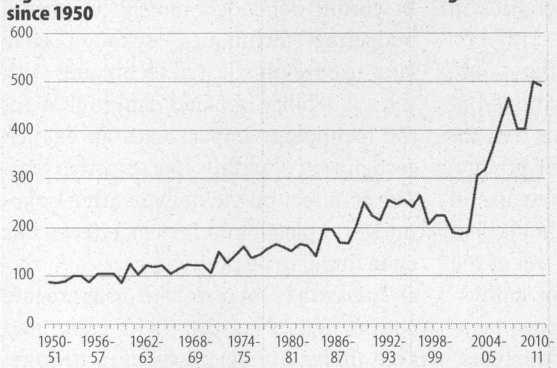
There has been a lot of divergence between the statistics generated by the above bodies. To sort out this issue, the

Figure 1: Relationship between Cotton Per Hectare Yield and Coverage under Bt Cotton




Source: Directorate of Economics and Statistics, Ministry of Agriculture.

Figure 2: Movement of Per Hectare Lint Yields in Kilograms since 1950




Source: Directorate of Economics and Statistics, Ministry of Agriculture.

government, on the advice of Abhijit Sen, entrusted the responsibility of undertaking a study to the Indian Agricultural Statistics Research Institute, New Delhi. The study by Ahmad et al (2009) concluded that the official estimates by the DES are based on a scientific methodology, which is objective, scientific and verifiable. According to them, the estimates of cotton production based on market arrival data also reveal that the official estimates seem to be closer to actual production than the CAB estimates. Therefore, it is imperative to take the figures of the DES for cotton statistics in general and per hectare yields in particular.

According to the DES data, yields increased from 191 kilograms per hectare in 2002-03 to 467 kg/ha in 2007-08, by which time biotech cotton occupied 66% of the cotton area in the country (Figure 1). However, Stone erroneously showed that this yield level was reached by 2004, and this is not the picture in official statistics. Further, his assertion that there was a decline of 7.6% in yields since 2006 is not true. They declined in 2008-09 and 2009-10 with adverse weather to pick up again to 499 kg/ha in 2010-11 and 491 kg/ha in 2011-12. Most importantly, the introduction of Bt cotton has halted the slide in yield levels that was observed after 1996-97, as can be seen from Figure 2.

## Selection Bias

The impact of any technology will be inflated when research studies compare efficient farmers adopting the technology with less efficient farmers without any method of separating them. Stone (2012) asserts that the problem is not handled with any success in studies. However, many studies have explicitly tried to do this and reported yield effects after controlling for the so-called "farmer effect". The four methods used for this purpose in the literature are using a sophisticated panel data fixed effects model; using regression equations that include socio-economic variables such as farm size, family size, education, age and experience that can make some cultivators more efficient; comparing the yields of adopters and non-adopters using a specific hybrid; and comparing the before and after adoption scenarios for late adopters.

Stephen Morse and his colleagues at the University of Reading have brought a series of papers using panel data collected from farmers' fields in Maharashtra that tried to isolate the farmer effect. While Crost et al (2007) have used the fixed effects model for this, Morse et al (2007a, 2007b) have gone further to explore the reasons for it. The former study controlled for selection bias and year-by-year variability and found a yield increase of 31% with the cultivation of Bt hybrids. Morse et al (2007b) concluded that the farmer effect of 29% to 43% observed by comparing the non-Bt plots of adopters and non-adopters was due to the adopters mostly cultivating the relatively high yielding and locally adapted "Bunny" hybrid. In other words, farmers achieved similar results once the genetic effect of Bunny is discounted, and there was therefore no selection bias (Morse et al 2007a, 2007b). Stone (2012) quotes the first part saying that the farmer effect is 29% to 43%, ignoring the subsequent analysis.

Matin Qaim and his colleagues collected data in four waves from 2002 to 2008 across four cotton-growing states from 533 households and published several papers that address several issues of the impact of Bt, including selection bias.[2] Applying a fixed effect model to their data, Kathage and Qaim (2012) found 24% higher yields and 50% higher profit. Using data collected at three points in time (2002-03, 2004-05, and 2006-07), Sadashivappa and Qaim (2009) have done robust checks to the yield effects by using a "damage control framework", which is more appropriate since Bt is a pest-mitigating (biotic stress) technology rather than a yield-enhancing one. They found that the yield effects are fairly similar, ranging from 22.2% to 45.2%. They also used non-Bt plots of adopters as a check to see the yield effect, and this gave almost the same results, indicating that the selection bias is small and without direction. Morse et al (2007a, 2007b) have also compared yields in Bt plots with non-Bt plots of adopters to find higher yields. These studies refute Stone's assertion that scholars hide data from non-Bt plots of adopters to cover up selection bias.

In our earlier article (Herring and Rao 2012), we presented costs, yields and returns before and after adoption from 186 cotton growers, with a 42% increase in yield. This methodology avoids selection bias, as the same farmers cultivate the conventional and Bt variants. Stone (2011) also followed the pre- and post-adoption scenarios, though he relied on an intensive season-long approach. It is well known that if systematic differences in efficiency or adoption are fully covered in the socio-economic and farm-level variables concerned and are included in regression, the selection bias is eliminated. Using this principle, a few studies (Naik et al 2005; Narayanamoorthy and Kalamkar 2006; Rao and Dev 2009) have used regression frameworks to find the yield effect by controlling for these variables that cause variations in efficiency, and found statistically significant gains.[3] The extent of selection bias varies, depending on the socio-economic characteristics of adopters, as seen from different studies. While Crost et al (2007) find it to be two-thirds of the total yield effect, Kathage and Qaim (2012) find it to be very small. Stone wrongly assumed that a high yield effect of 80% in one year and lower yields (24%) in panel data models are as a result of selection bias. The differences in yield effect cannot be attributed to selection bias alone, as other issues such as pest pressure, germ plasm and so on influence yield levels.

## Cultivation Bias

Stone argues that higher doses of inputs such as fertilisers, labour and irrigation are applied to Bt plots, leading to a cultivation bias, and implying that the higher yields are a result of higher input levels rather than the Bt gene. A crop suffering from bollworm attack stress cannot assimilate normal doses of input since it does not allow it to reach its genetic potential, thereby reducing the yield. When the Bt gene affords protection against the bollworm and reduces the gap between the potential yield and actual yield, the plants require higher doses of inputs compared to earlier. The farmer is likely to put more effort and money into the crop with a higher level of technology because he is assured of a higher output. However, the issues here are whether biotech cotton yields are higher in relation to the inputs applied, and whether research studies have controlled for the impact of the other inputs and isolated the true impact of the Bt gene.

Most of the studies have reported a higher cost of production in the cultivation of the biotech cotton. However, as a result of higher yield, the average cost of production (the production cost per quintal) is lower than conventional cotton, making it more profitable. For example, Rao and Dev (2009a) report a decline of 11% and 31% in 2004-05 and 2006-07 in the cost of production, even after including imputed costs like rental value of owned land, cost of family labour, and interest charges. Similarly, Kathage and Qaim (2012) found a 15% and 10% decline during 2002-04 and 2006-08, and Narayanamoorthy and Kalamkar (2006) found a 10% decline. The real test for any superior technology is to shift the production function upwards or cost function downwards. Shifting the production function upwards means producing the same level of output for a given level of inputs, while lowering the cost function means producing each unit of output at a lower cost. Rao and Dev (2009a) have shown a downward shift of the cost function by comparing before and after adoption scenarios in Andhra Pradesh.

Much of the criticism of the Cobb-Douglas (C-D) production is targeted at questioning the validity of this tool for testing the theory of marginal productivity and does not pertain to its use in the analysis of farm household data (Biddle 2011).[4] Therefore, the use of the C-D function for controlling for cultivation bias is not "flawed" as Stone mentions. Now, when we examine the literature, several studies have used the production function approach to control for the effect of using different farm inputs such as fertilisers, pesticides, irrigation, labour and other inputs and found significantly positive yield impacts (Bennet et al 2006; Qaim et al 2006; Narayanamoorthy and Kalamkar 2006; Crost et al 2007; Morse et al 2007b; Rao and Dev 2009; Sadashivappa and Qaim 2009; Loganathan et al 2009; Kathage and Qaim 2012; Ashok et al 2012). Some scholars have separated the Bt gene effect and germ plasm effect and still found a 37% higher yield (Naik et al 2005). An innovative study by Ashok et al (2012), using a big sample of 320 adopters and 120 non-adopters in four states in 2007-08, decomposed the input effect from the technology effect and found that 54% of the estimated yield advantage was due to technology.

## Conclusions

The issue of finding out the exact effect of an agricultural technology poses several difficulties in view of the diverse agro, economic, social and environmental factors, and soil fertility-related, policy-related, and adopter-specific variables. No single method or tool can conclusively prove its utility or the lack of it through isolating the exogenous variation by separating the endogenous variables. A combination of methods used across different locations and groups of adopters will enable arriving at appropriate conclusions.[5] The length of time the technology has been adopted and the depth of adoption also matter. A number of studies using different methods in different areas and time periods have found statistically significant positive yield effects. While initial studies on Bt cotton depended mostly on partial budgeting techniques, scholars have later used sophisticated techniques with the availability of panel data to find out the technology impact with an explicit recognition of pitfalls like selection bias. The Bt effect on yield, even after isolating germ plasm and farmer effects, has been found to be positive.

There was a lot of debate on aggregate cotton figures as the yield gains and area under Bt hybrids seem to diverge. However, this is because of the accepting of trade statistics without appreciating the differences in data sets. The area, production and yield figures have to be based on Ministry of Agriculture statistics rather than the CAB, as they are compiled using a scientific methodology.

To conclude, though Stone's article has succeeded in highlighting problematic issues in accounting for farmer effect and the preferential treatment in impact studies, it has failed to examine the accumulated evidence and arrive at proper conclusions. In the final analysis, his article does not differ from anti-genetically modified (GM) campaigners' claims of failures and is deeply sceptical of technological innovation leading to the modernisation of agriculture. This modernisation has a positive social welfare impact with unprecedented increases in yields. For example, the wheat yield in the UK took 600 years to increase by one tonne from 400-700 kg/ha to 1.7 tonnes in 1850 before Mendelian genetics accelerated production to five tonnes in just 90 years from 1900.[6] Similarly, the cotton yield in India doubled from 88 kg of lint per hectare in 34 years from 1950 to 1984, and it took less than a decade after the advent of biotechnology to double after 2002. It is important to look at this in a historical perspective to understand the true value of technology. It is nobody's case that biotech cotton alone made the difference, but it is incontrovertible that Bt cotton has played a major part.

## NOTES

1 See CCI (2011).

2 Qaim and Zilberman (2003) solve this problem by using trial data, where Bt hybrid is compared with its non-Bt counterpart being cultivated by the same farmer.

3 As is common, we tried all socio-economic variables in regressions, but finally included significant ones leaving out insignificant ones in Rao and Dev (2009).

4 Including the criticism by McCombie (1998), mentioned by Stone. McCombie (1998) bases his critique on the arguments developed by Brown in 1957, and formalised by Simon and Levy (1963).

5 Smale et al (2009) and Ravallion (2005) arrive at similar conclusions from their reviews of studies on transgenic literature and anti-poverty programmes, respectively.

6 See Plucknett (1993).

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