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Performance of Genetically Modified Cotton: A Systematic Review Findings

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Abstract

The benefits of transgenic cotton continue to be disputed, despite rapid and widespread adoption since their commercial introduction in the United States in 1995 and first planted in 1996. Since the first debut on U.S cotton farms, biotech cotton rising growing area which mostly derived from the yield gain and increasing farmers income. There is a general belief that the development of cotton biotechnology will be a major factor in boosting productivity in agriculture around the world. This study aim to provide an overview of the current state of knowledge the performance of this technology worldwide based on a wide range of data and source from available literature. To this end, we investigated the benefits of implementing Genetically Modified Cotton in developing countries particularly in China and India as the systematic review which captured to provide the evidence of potential benefits of cotton biotechnology. In summary, this paper depicts positive impact of commercialized this technology in terms of net revenue and the benefits, especially in terms of increased yield, are greatets for the mostly farmers in China and India who have benefitted from the spill over of technology targeted at the farmers in developed countries.

Keywords: Transgenic, Yield, Income, Farmers, Benefits

1. Introduction

The development of transgenic cotton cultivars delivers cotton produces more options for managing pests, but their value to producer depends not only on the cost savings that they may contributes to the pest management system employed, but also on the gross revenues from the sale of the crop produced. For Instance, performance studies demonstrated 10-20% yield increase for hybrid transgenic cotton compared to purebred transgenic cultivars or hybrid and non-hybrid conventional cultivars [5]. Moreover, analyzed the impacts of Bt technology on cotton yields, profits and household living standard in India by using panel data during 2002-2008 period which covers four states of India shown that Bt adoption has positive and significant net impacts. This technology has increased per acre cotton yields and profits by 24% and 50%, respectively, and stated clearly underline that Bt cotton has significantly increased living standard of smallholder farm household in India [15].

It is now almost two decades since the first GM crops were introduced into agriculture. Since the first commercialization of GM cotton, during the decade 1995-2015, several studies on GM cotton in developing countries claimed that its use bring benefits tosmallholders because it increased yields [37], and according to [16], there is substantial evidence that the adoption of Bt cotton provides economic benefits for farmers in a number of countries. In relation to socio-economic impacts. [3] reveals that covers 12 countries worldwide and summaries results from 49 peer-reviewed publications based on report on farmers surveys comparing yields and other indicators of economic performance for adopters and non adopters of being commercialized GM crops indicated that benefits from growing GM crops mainly derive from increases yields, which are greatest for small scale farmers in developing countries insofar as they have benefitted from the spillover of technologies originally targeted at farmers in industrialized countries.

This study, more specifically, it is noteworthy to point out that the main objective of this paper is to review the wide range of meta-data from the individual studies which focussed on yield performance and economic performance in order to documented the potential benefits of using GM cotton over its counterparts in developing countries particularly in China and India. A literature review of academic articles, news articles and publicly available project documents were considered in this paper.

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2. Materials and Methods

2.1. Overall Approach

Data and information in this study were collected as the key element and set as data base then adjusted by taking into account, in particular, the condition under which main parameters of economic performance reported in the literature. This literature was formed as the backbone of this study providing data and information associated with economic indicators on GM cotton performance. Many body evidences used as a data source for this study had to contain raw data on at least one of the parameters of economic performance of GM cotton and its counterparts: crop yield, revenue, gross margin or costs (of seeds, management labor, pesticides and herbicides). This study was covered at the country level in China and India what effect GM cotton on crop yields and assess the effect of GM cotton on farm level costs and benefits. The review and meta-analysis were presented on this study extends the existing literature and by focusing on a wide scope of papers. Moreover, the collection of observations from more than one decade of field trials and surveys allows for the trend analysis in the performance of GM cotton [16]. This study also considered reveals limitations for meta-analysis on farm level cost and benefits of GM cotton which rely on different assumptions, purposes and methodologies (e.g., surveys and field trials).

In which to collect the literature, a keyword search was carried out initially on specific literature databases such as the web of sciences, the web of knowledge, Research Paper in Economics (RePEc), Research in Agricultural and Applied Economics (AgEcon-search) and others, whilst further sources will search through google scholars. The key words “GM cotton”, “transgenic cotton”, “Bt cotton”, “economic performance”, “input cost”, “yield”, “benefit”, “income” or “revenue”, etc. and combinations were used. To ensure that the data had not been repeated or even misinterpreted in the source document, the screening of the publication often led to another source to track primary data. Such an approach was considered to be necessary in order to avoid the publication of data and possible bias derived from citation and re-interpretation of data by different authors [6].

2.2. Study Design and Data Gathering

The database was designed which consists of a number of different sources which only publication that contained data on at least one of the investigate economic parameters (yield per hectare, costs of herbicide and pesticide per hectare, seed costs and gross margin per hectare) rather than qualitative statements would be considered in the data base and by indicating the methodology of data collection applied in the study (field trials, interviews, reviews, etc). This allowed for the classification of publication and a study according to its scientific reliability.

Different parameters were chosen to assess the economic performance of transgenic cotton, depending on the availability and format of the data. In this study, yield per hectare, costs of herbicide and pesticides per hectare, seed costs, and gross margin per hectare turned out to be the most valuable. For other input costs such as fertilizer, labor and management and post-harvest processing, only limited information could be derived from the literature. Due to strong variation in data presented in the different individual studies and for analytical reasons, gross margin per hectare was regarded as the most comprehensive measure to compare the economic performance of GM cotton and its counterparts, as it captures both costs and benefits which are often not further specified in the studies. However, it must be acknowledge that the way in which gross margin was calculated did vary between studies, making it difficult to directly compare values [6]. Furthermore, the data base included general information on the cotton traits (herbicide tolerance, stacked gene, Bt and conventional cotton).

The database included peer-reviewed scientific articles as well as non peer-reviewed sources which include raw data on the economic parameters. Non peer-reviewed sources in general from governmental organizations or agencies/institutes funded by governments, international organization and national/international statistics as well as conference proceeding, and also from academic, governmental, from civil society or from a company. Following the methodology outlined above, studies of non peer-reviewed sources that were used in peer-reviewed publication to conduct comparative analysis, were entered in the database by assigning a conductor of the study, which can be academic, governmental, from civil society or from a company.

3. Results

Bt cotton farmers in China are typically small producers and are usually resources poor and risk aversive with an average crop area of less than 1 ha per household, of which the cotton area less than 0.5 ha [9]. China is a great country in terms of transgenic cotton technology, since the first year commercialization in 1999, this technology had rapidly adopted. For example, in Shandong farmers had converted the conventional cotton since 2002. In the other word, there were no conventional seeds in Shandong province in 2002. Only two years needed China had successfully spread this technology at that time, spill over among the farmers. Fig. 1 represents the Bt cotton adoption in China.

Fig. 1 depicts the percentage of Bt cotton adoption between 1997 and 2008 in China with 4 sample provinces. This reveals that since 1997 Bt cotton has been adopted by the farmers in Hebei and Henan then has been spread widely in Anhui and Shandong. In the following years we found that Bt cotton adoption was increased sharply 100% between 2000 and 2002 in Shandong, whilst in Hebei rose dramatically between 2000 and 2004. Moreover, in Anhui and Henan Bt cotton adoption has been adopted widely in

2008 by 90% and 85%, respectively. [13] stated that the cultivation of Bt cotton has steadily expanded outside of the study areas to more southern provinces, e.g. Jiangsu and Hubei. This is indicates that since 2001 conventional cotton was disappeared in Shandong and Hebei, whilst in Anhui and Henan conventional cotton was not available in 2008.

The promise of benefits of Bt cotton in China is still no doubt when compare with non- conventional cultivars particularly in terms of yield potential and net revenue derived from planting transgenic cotton. Fig. below describes yield result of Bt cotton and its counterpart.

Moreover, it is remarkable that mean yields of Bt cotton were higher than conventional cotton in all years except in 1999 it was slightly different that non-Bt cotton higher than Bt cotton, the Bt cotton yields have remained high in subsequent years (Fig. 2).

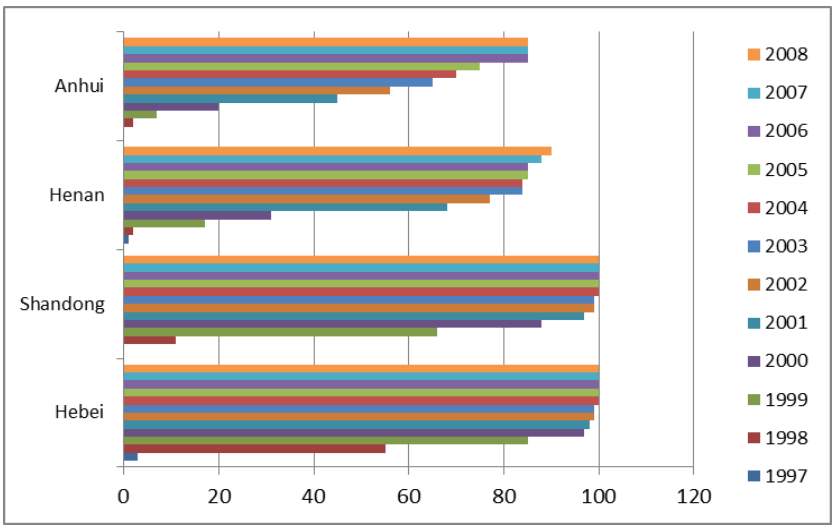

Fig. 1. Bt cotton adoption (%) in China and Samples Provinces, 1997–2008 (Source: Huang et al. 2010).

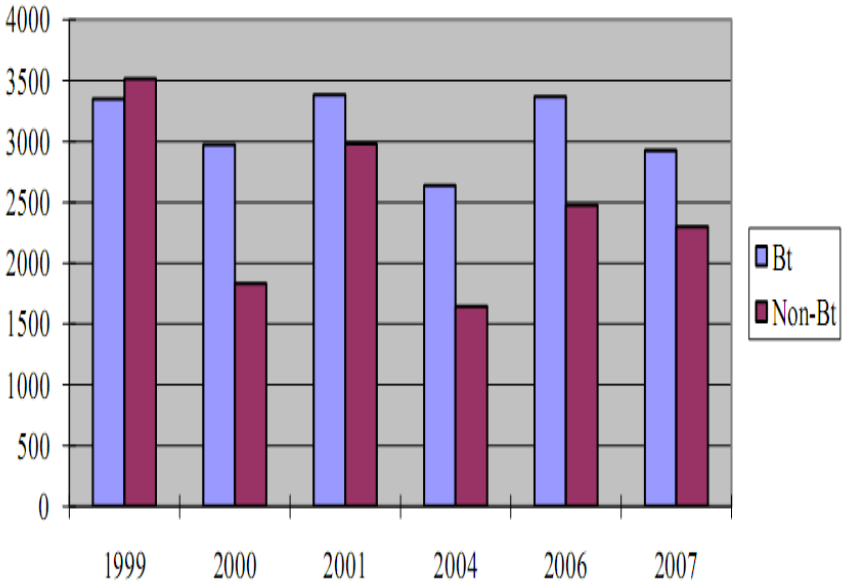

Fig. 2. Yield of Bt cotton Vs Conventional Cotton in China (Kg/Ha).(Source : Adopted from Pray et al. 2011).

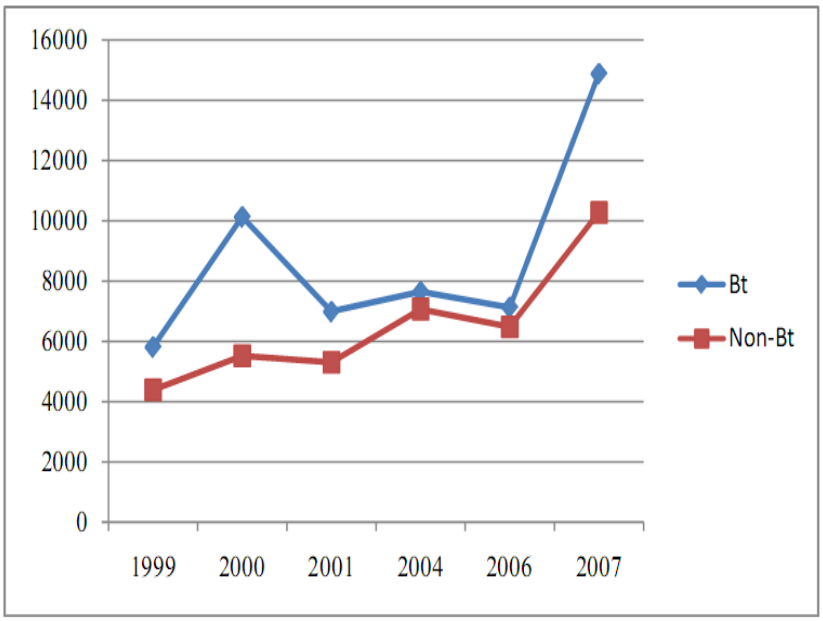

Fig. 3. Net Revenues (RMB Yuan current prices) from Bt vs. non-Bt cotton among surveyed villages in China, 1999-2001, 2004, 2006, and 2007. (Source : Adopted from Pray et al. 2011).

Fig. 3 is notable fluctuation trends describe Bt cotton net revenue between 1999 and 2007, meanwhile conventional varieties have upward trend from 1999 to 2007. The year of 2007 is the highest net revenue of Bt cotton probably due to the high yield cotton price at that time [24]. The yield of conventional cotton is not stable, however, the net revenue of conventional cotton gradually increased from 1999 to 2007, this is due to the high yield cotton price of conventional cotton that is indicate improved. Moreover, the net revenue of Bt cotton and its counterpart in 2004 and 2006 was not significantly different, meanwhile the cotton yield of Bt and non-Bt in 2004 and 2006 was highly different. It is also indicated that the conventional cotton more effective in terms of economic benefits at that time.

In India, cotton is an important cash crop in India and plays a significant role in the national economy, contributing about Rs. 360 biliion (US$8 billion) towards export income and 4% of GDP. It is estimated to support about 60 million people, including farmers who cultivated the crop and those involved in the cotton industry for processing and trading [20]. Most of Bt cotton growers in Indian, like in China, are small-scale farmers; several studies in the past of ten years Bt cotton commercialization have shown that they benefit considerably from adopting this technology in terms of reduction in pesticide use and higher effective yield [17, 1, 10, 11, 30]. In addition, according to [32] showed that Bt technology increased yield ranged from 30% to 40% and reducing the numbers of chemical sprays by 50% consequences an generating additional farmers' income of US$156 per hectare. It is notable that the economic benefit recorded in pre-commercializing field trials are consistent with the actual experience of farmers commercializing Bt cotton during the eight year period 2002 to 2009.

Fig. 4 reveals the differences of yield gain and net return based on the peer-reviewed and non peer- reviewed across the regions in India. Studied in Tamil Nadu in the year of 2004-2005 by [18] reported that Bt cotton yield was definitely much higher than its conventional and also was the highest yield than any other transgenic varieties. This graph illustrates that Bt cotton yield has a stable pattern over time across the regions in India. Several studies based on the meta-data suggest that Bt cotton provide the evidence that its performance gain high yield advantage compare to its conventional. Fig. 8 depicts that overall results transgenic cotton in yield gain is relatively higher than its conventional. A little bit surprisingly, we found lower yield of transgenic cotton over non transgenic cotton assessed by [31] in 2003, and slightly different researched [27, 22, 2]. Therefore, study findings suggest that the outstanding lesson from the studies published to date is that the performance of transgenic cotton has varied widely, across farms and farmers, parental varieties, regions and seasons.

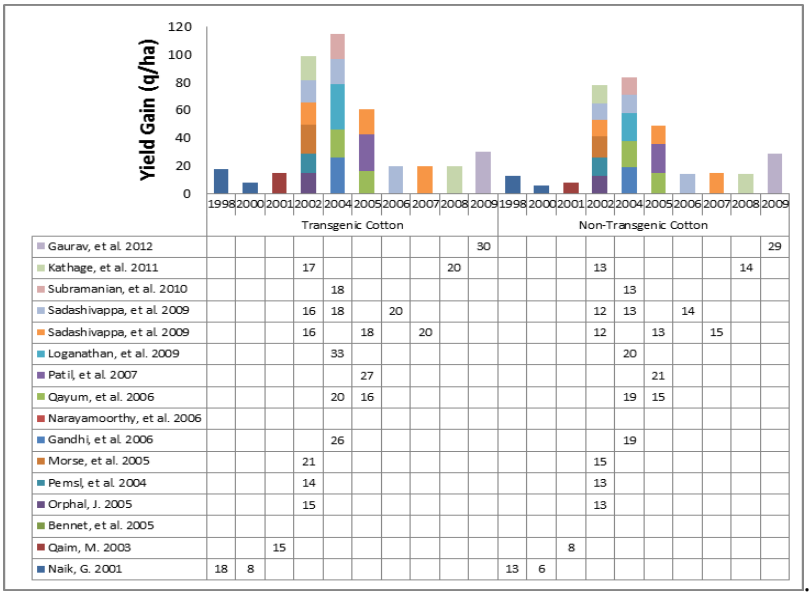

Fig. 4. Agronomic performance of Bt cotton over its counterpart across regions over time in India.

Fig. 5 reveals the highest net return founded by [18] in the year of 2004 (USD 1,014.7/ha), and the lowest founded about USD -164.9/ha in 2009. Whilst non Bt cotton counterparts ranged between USD 19/ha and USD 626/ha. To date, study findings that the results of large number studies indicate that net return of Bt cotton is higher than non Bt cotton except study by [23] in [31] in Andhra Pradesh in Gujarat. According to [18] reveals that higher profitability was the top most reason for choosing to grow Bt cotton. In this regard, study suggests that it is clearly shows that the profit realized from Bt cotton is substantially higher than that of non Bt cotton.

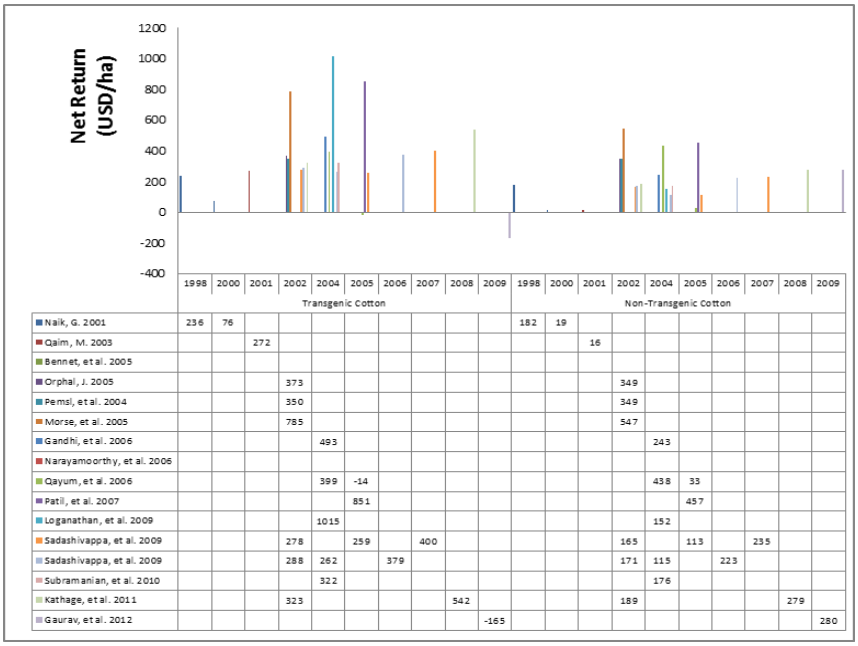

Fig. 5. Net returns of Bt cotton over its counterpart across regions over time in India.

4. Discussion

Most published evidence to date indicates that GM cotton has had a positive economic impact for small-scale farmers in developing countries such as China and India and also in developed countries. Broadly they indicate an increase in yield, reduced insecticide use (insecticide product per hectare), reduced expenditure (as less pesticide is used) and an overall increase in the gross margin for GM cotton varieties compared to non-GM cotton varieties. Study findings that gross margin or net revenue of GM cotton is substantially higher over its counterpart. However, we found that some of the individual studies did not measure the economic analysis appropriately. These included in 'all costs' is pesticide, labor, fertilizer, planting material, running costs of machinery etc. These are variable costs and yield tends to increase as variable costs increase, albeit within the limits of diminishing returns. In contrast, while revenue is relatively straightforward to identify, the problem lies in calculating costs.

Several early studies relied heavily on data derived from experimental plots which researchers established and managed on farmers' land, but critics were quick to label such work as unrepresentative and potentially biased. Other studies avoided this problem by focusing on plots owned and managed by farmers. Such methodological variations make comparison between studies difficult, even if the work has been carried out in the same country. Data analysis from such studies has typically employed multiple regressions, with yield as the dependent variable and the various inputs as independent variables. However, even if data are available the studies are typically focused on gross margin assessed over a short time period, possibly a single or a few growing seasons. They provide snapshots rather than a long-term picture, and fail to answer key questions about the sustainability of an increase in gross margin.

This study based on the meta-data relied on the individual studies and those came from the field trials, plots experiments, and farm survey. According to [16] the experimental setup of field trials may bias the derived economic performance results in several ways that side-by-side varietal trial, bias can occur through the so called "halo effect" that comes in when insect repellent used for GM cotton spill over onto the conventional treatment. Papers by [4, 19] this "halo effect" might have impact of source of pest control, which may increase the yield of the conventional tested. Subsequently, yield increase due to GM cotton adoption might be underestimated in such field trial.

A common method to assess the economic performance on farm level is farm surveys to compare new variety over its counterpart. According to [34, 19] found that a major drawback of several survey based studies is lack of basic information about the sampling procedures. [16] stated that selection biases also occur if participating farmers are chosen on the basis of their willingness to cooperate and a minimum endowment with productive sources such as described by [30] we found that the trial sites were monitored by Mahyco scientist; and used data collected by Monsanto's partners [1, 30]. Another shortcoming within the survey is the answer farmers when they asked about past input allocation decisions that we doubt they can remember precisely during the interview. This is consistent with [21] stated that most of the data survey were based on records kept by the farmers and in the absence of receipt farmers were asked to recall their input use and expenditure. As a results there were some missing data where farmers either did not have the record for a particular input, could not remember or where a mistake was made in recording by the enumerators. Therefore, it should be noted that potential weakness of the survey was the lack of the data collected on other inputs to production such as labor. Such data are difficult and expensive to collect, and quality can be debatable given that there is a reliance on memory. Study findings that most of the individual studies were used to survey method to assess the economic performance in comparing between GM cotton over its conventional such as [25, 26, 27, 35, 9, 10, 11, 14, 27, 36, 21, 18, 17, 7, 23, 28]. Thus, using meta-analysis we found some individual studies are not statistically significant or even the results are different in comparison between GM cotton and non GM cotton but actually are not greater or not highly significant.

5. Conclusion

Peer-reviewed surveys and field trials indicate positive impacts of commercialized GM cotton in terms of net revenue with few exceptions, that GM cotton have benefitted farmers in developing countries. The benefits, especially in terms of increased yields, are greatest for the mostly farmers in developing countries who have benefitted from the spillover of technology targeted at farmers in industrialized countries. The results of yield indicates that farmers in developing countries are achieving greater yield increases than farmers in developed countries. The largest yield increase found in this review (country-specific analysis) are reported for GM cotton in China.

We generally concur that Chinese consumers are more accepting of biotech cotton than are consumers in other countries. For this review, and for the methodological reasons, the accumulated evidence from individual studies based on the farmers survey, field trials and plot experiments on the performance of GM cotton helps to explain the widespread popularity of this technology in several regions across the world. Moreover, the wide spread of GM cotton among the farmers worldwide over time indicate a strong evidence that this technology has been adopted.

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