***Review paper***

# TRANSGENIC COTTON DEVELOPMENT: AGRO-ECONOMIC ANALYSIS AND COMPARATIVE STUDY


## ABSTRACT

The development of transgenic crop since its first launched to the public in 1995 results in high expectation in order to boost the agricultural productivity, particularly in cotton. Higher yield and higher return are the expectation of cotton growers especially for poor-resource farmers due to low income household. This study provides the evidence of implementing Genetically Modified (GM) cotton based on the meta-data which derived from indvidual studies more than one decade in China, India, USA and Australia as the comparative study. Economic performance is the analysis of economic indicators such as yield gain, seed cost, pesticide cost, management and labor cost, and net return in which the comparison between GM cotton and its counterpart worldwide overtime. Study findings that it is clear that this technology is not superior and still need to be suitable for the given production situation, and also depending on the specific pest pressure and other relevant local condition to optimize per hectare returns. This study results that this merit technology can vary in different ecological environments.


**Key Words:** Transgenic Cotton, Potential, Economy, Meta-Data, Technology

## 1. INTRODUCTION

Cotton is important for many developing countries, either as a cash crop and/or as an input into their textile industry. It is receiving more attention of late for two reasons. One is because, thanks to genetic modification using modern biotechnology, new insect-resistant and herbicide-tolerant cotton varieties are emerging that are proving to be more productive than traditional varieties of cotton. [1] Bt cotton, with engineered protection against tobacco budworm, bollworm and pink bollworm, was produced in the late 1980s by Monsanto, one of the world‟s major agrochemical companies. This Bt cotton underwent field trials in the USA in the early 1990s and following approval from the EPA cultivation of Bollgard®, the commercial name for Bt cotton, began in 1996 in the USA and in 1997 in China. Soon after a further 13 countries approved Bollgard®, including South Africa and in 2002 it was adopted, after regulatory studies which began in 1995, in India These are the major transgenic cotton-producing countries today [2].

Moreover, further commercial products have been developed e.g. RoundupReady® cotton (i.e. with herbicide resistance), which has been commercially available since 1997 and which is grown only in the USA. Bollgard II® is an improved version of the original Bollgard® cotton; it contains two genes from B. thuringiensis which confer resistance to a wider range of insect pests including budworms, bollworms, armyworms and loopers, plus saltmarsh caterpillars and cotton leaf perforators. It was approved in the USA in 2002 and first planted in 2003. Subsequently stacked gene varieties of GM cotton have been develped. These comprise varieties with Bollgard® plus RoundupReady and Bollgard II® plus RoundupReady® Flex cotton (the latter has improved herbicide resistance) with both insect and herbicide resistance [2].

Given the development of genetic modification since the its first launched which has been spread among the farmers worldwide will be driving a question what has been experience so far in terms of the contribution they can bring a large size of economic value for cotton growers. This paper through the meta-data based on the individual studies more than one decade since 1996 provides the data and information in agro-economics of the GM cotton performance as comparative study of the benfit of GM cotton over time.

## 2. AGRO-ECONOMIC PERFORMANCE

Higher yield and higher economic value is the most important thing as the high expectation of cotton grower. Moreover, economic indicators such as seed cost, pesticide cost, management and labor cost should be considered as the whole economic analysis. A significantly higher cotton yield due to the adoption of transgenic cotton can be seen at Table 1 which is indicated in China and India. The estimated yield increase due to the Genetically Modified (GM) cotton ranges from 5.6% in Australia and USA to China (18.4%) and 33% in India. A cross country analysis proof the evidence that seed cost, as the consequences of using transgenic cotton is much higher than its conventional. There were significantly higher seed cost for transgenic cotton than its counterpart in the cases of China, India, and USA. The estimated of mark-up of seed cost for GM cotton ranges from 51.9% (China) to more than 100% in India and more than 200% in USA. Put another way, seed cost in China is the cheapest input compare to any other country.

Table 1. Economic performance indicator of meta-data analysis by country and by Trait

| Country | Trait | Economic performance indicator (Average) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Yield (Kg/ha) | Seed costs (US$/ha) | Pesticide costs (US$/ha) | Management and labor costs (US$/ha) | Total Cost (US$/Ha) | Net Revenue (US$/ha) |
| China | Transgenic | 3080*** (1.0182) | 58.65 (11.8293) | 61.3*** (28.9172) | 949.79 (308.7673) | 1069.74 | 672.56 (601.8637) |
| | Non Transgenic | 2600 (0.8608) | 38.59 (21.7072) | 191.5 (162.2929) | 1094.9 (292.9018) | 1279.99 | -41.28 (408.2033) |
| | % Change | 18.4 | 51.9 | -67.9 | -13.25 | | 1720.9 |
| India | Transgenic | 1920** (0.57920) | 76.83 (13.2792) | 76.9*** (37.5295) | 365.21** (207.6711) | 518.94 | 402.43*** (288.1860) |
| | Non Transgenic | 1440 (0.4468) | 27.0 (6.3946) | 111.87 (51.3595) | 293.99 (105.0056) | 432.86 | 270.64 (151.1514) |
| | % Change | 33.0 | 184.5 | -31.25 | 24.22 | | 48.69 |
| USA | Transgenic | 1250** (0.42599) | 108.52 (52.89003) | 102.18** (109.260) | 192.06 (212.2875) | 402.76 | 1212.0* (570.9904) |
| | Non Transgenic | 1183.3 (0.4369) | 34.05 (17.7358) | 113.61 (135.6949) | 194.68 (198.9211) | 342.34 | 1055.1 (435.56654) |
| | % Change | 5.6 | 218.7 | 10.0 | 1.34 | | 14.87 |
| Australia[1)] | Transgenic | 1680** (0.2573) | n.a. | 503.73*** (110.8874) | n.a. | n.a. | n.a. |
| | Non Transgenic | 1590 (0.4748) | n.a. | 643.26 (144.6791) | n.a. | n.a. | n.a. |
| | % Change | 5.66 | n.a. | -21.69 | n.a. | n.a. | n.a. |

Note : standard deviation in parentheses
1) Due to the low number of observations, transgenic cotton in Australia are not statistically analyzed
*,**,*** denote significance at the 10, 5 and 1% level respectively (comparison are made by t- test)

Higher yield and higher economic value are the grower expectation by using high technology and needed to proof that cotton biotechnology is positively associated with high income. Transgenic cotton are expected to be used as the novel technology which resistant to insect pest and to be highly beneficial through reducing of pesticide usage despite the high cost of transgenic seed. This sub-chapter provided the comparison information focusing on yield and net return as the noteworthy component in the economic indicators and provides the comprehensive study across country based on the database set which have collected in this study. Meta data found that some of the data from the authors are not available because there is no information from them, and it is difficult to investigate it. It is compelling that comparative study wants to show the data and the information from the authors in terms of the differences of yield and net return between transgenic and non transgenic cotton over time.

## 3. COMPARATIVE STUDY

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. Figure 1 represents the Bt cotton adoption in China.

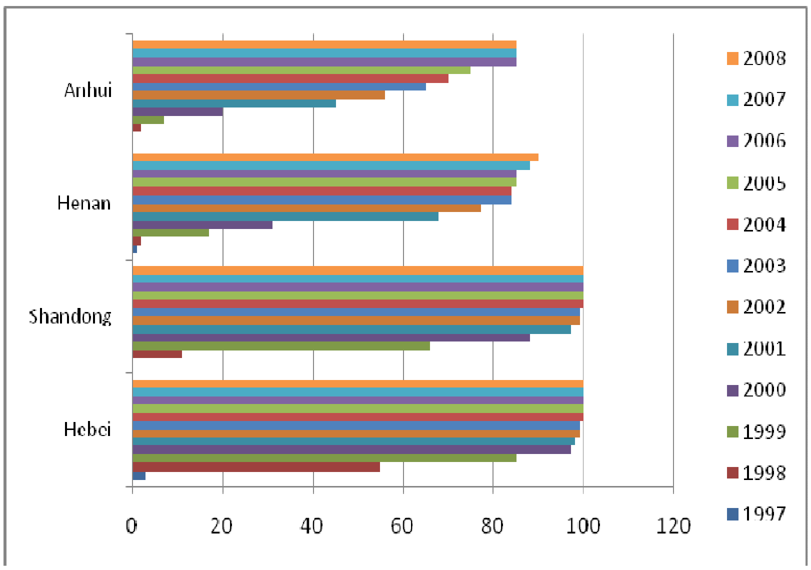



Figure 1. Bt cotton adoption (%) in China and Samples Provinces, 1997–2008. Source: [3]

Figure 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 subsequent 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. Indeed, the cultivation of Bt cotton has steadily expanded outside of the study areas to more southern provinces, e.g. Jiangsu and Hubei [3]. 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. Therefore, study findings about the comparison between Bt cotton and non-cotton in China has been not provided since 2004 particularly in Shandong, Hebei and also in Henan and Anhui in 2008. To sum up, the area planted in Bt cotton has increased sharply since its commercialization in 1996, and therefore conventional cotton was disappeared in some regions dramatically.

Moreover, we presented the data which can be seen at Table 2 about yield gain and net revenue using Bt cotton over its conventional over time in China. The data which derived between 1999 and 2001 indicated that Bt cotton yield was higher than its conventional even it is not actually greater [3]. The differences between Bt cotton and its counterpart from 1999 to 2001 in some different regions (Mostly data collected in Shandong, Hebei, Henan, Anhui and Jiangsu) in China ranged between 29 q/h and 34 q/ha for Bt cotton and non Bt cotton ranged between 19 q/ha and 32 q/ha. [4] One study found that the adoption of Bt cotton had a minor impact on yield gain compare to its conventional based on the farmer's survey in Shandong, Hebei and Jiangsu between 2001 and 2002, respectively. Moreover, [5] another study finding in 1999 shows that there is no significant different between Bt cotton and its counterpart in Shandong (33 q/ha and 32 q/ha, respectively).

Study of the commercial growing of different varieties of *Bacillus thuringiensis* (Bt) cotton compares the performance of growing conventional across the regions in China suggest that overall Bt cotton are higher than its conventional but are not highly different, yet its yield performance is little better than non-Bt cotton (Figure 2). In terms of net return we can see at Figure 7,overall, it can be stated that Bt cotton had significantly higher than non Bt cotton which ranged between USD 1,558/ha and USD -310/ha. The data derived from different authors, looking not simply at differences between transgenic cotton and its counterpart in terms of economic performance. This study ignore how to measure net returns among the authors, even the meta data found that some of the authors could not figure out the net returns precisely and although it is debatable there is no space here to discuss it.

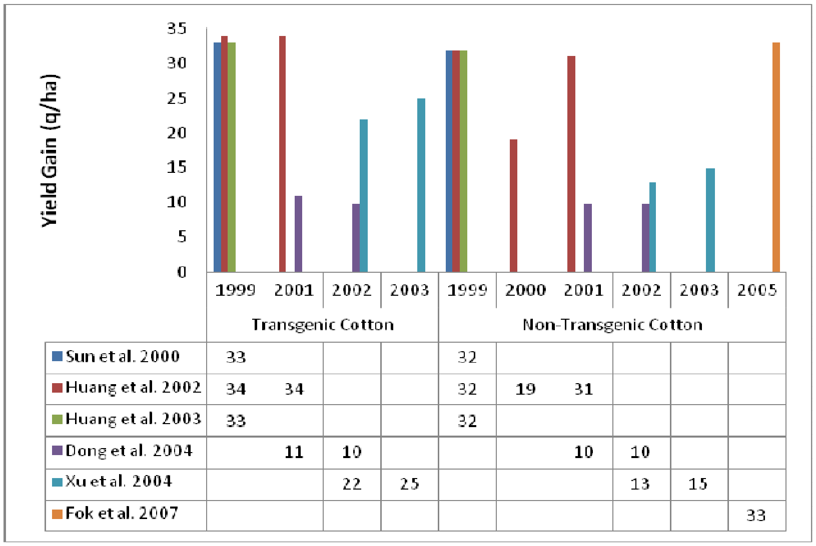



Figure 2. Yield Gain of Bt cotton over its counterpart across regions over time in China

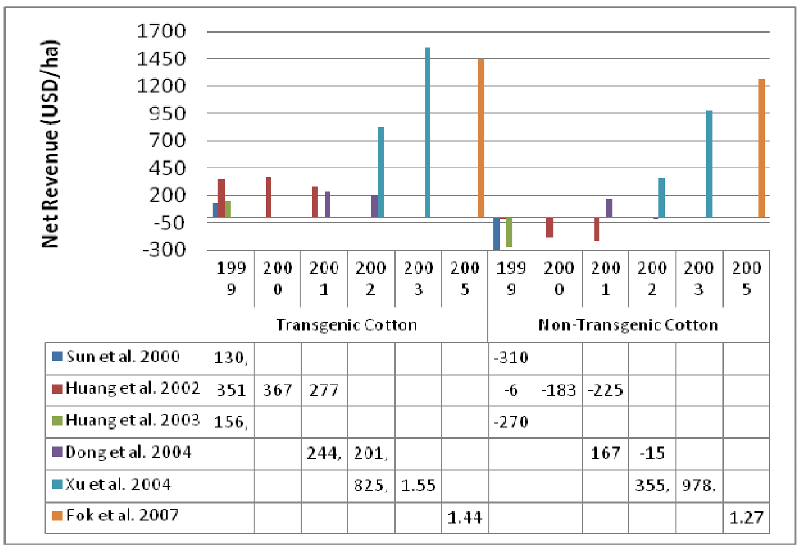


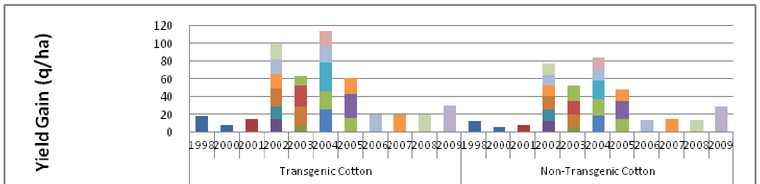

Figure 3. Economic performance of Bt cotton over its counterpart across regions over time in China

Figure 3 reports that all of non-Bt cotton varieties across the regions in China between 1999 and 2002 which rely on the individual studies resulting in negative value, whilst the transgenic cotton had the positive value. Study also found negative net return [5] in Shandong province by the year of 1999 (USD -310/ha) and [6] data from Hebei and Shandong in 1999 (USD-270/ha).  This result is consequential. Therefore, China became a great country which rapidly adopted transgenic cotton. This data automatically answer that farmers in china preferred to choose Bt seed converted their growing area of cotton. Consequently, nowadays it is difficult to find out non transgenic seed among the farmers across the regions in China. Thus the data of non Bt cotton since 2005 was not available in this study. Surprisingly (see Table 2), [7] from the field trials in 2003 shows highest net return (USD 1,558) of Bt cotton compare to any other study. [8] Study from the survey in Jiangsu in 2005 shows the highest value of non Bt cotton by USD 1,271 among conventional cotton.

In assessing the empirics of Bt cotton, there are two nested but separable question, one agronomic, one economic. Yield measured is the one of agronomic aspects, and net return is the one of economic indicators. Meta data study in India found a group of researcher and industry writers have constructed a narrative of technology merit for Bt cotton, based on an empirical record of superior performance compared to conventional seed. Mostly, data sourced from the industry journal authentication system which creates pro-GM facts through the interaction of a different set of interested parties. Study found that not only the proponents but also the opponents staked out their position during the field trials. Table 3 shows the proponents and opponents of this technology and see the differences between transgenic cotton and its counterpart in terms of yield and net returns.

Table 3 reports counterfactual study in India between transgenic cotton and its counterpart based on the different authors which have conducted their study from 1998 to 2009. Yield difference between transgenic cotton and non transgenic cotton is fully vary across the regions in India. For example, in some regions such as in Gujarat and Karnataka Bt cotton somewhat higher than non-Bt cotton, whilst in other regions Bt cotton is significantly higher than its conventional. However, meta data also found that transgenic cotton production is lower than its counterpart in Andhra Pradesh. In the case of net returns based on the database shows that in some regions Bt cotton has strongly positive net impacts, although this study found that Bt cotton has negative net impacts in Gujarat, and also shows that conventional varieties gained higher profit than Bt cotton in Andhra Pradesh.

Figure 4 reveals the differences of yield gain and net return based on the peer-reviewed and non peer- reviewed across the regions in India. [9] Studied in Tamil Nadu in the year of 2004-2005 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.




| | Transgenic Cotton | | | | | | | | | | | Non-Transgenic Cotton | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1998 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 1998 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
| Gaurav, et al. 2012 | | | | | | | | | | | 30 | | | | | | | | | | | 29 |
| Kathage, et al. 2011 | | | | 17 | | | | | | 20 | | | | | 13 | | | | | | 14 | |
| Subramanian, et al. 2010 | | | | | | 18 | | | | | | | | | | | 13 | | | | | |
| Sadashivappa, et al. 2009 | | | | 16 | | 18 | | 20 | | | | | | | 12 | | 13 | | 14 | | | |
| Sadashivappa, et al. 2009 | | | | 16 | | | 18 | | 20 | | | | | | 12 | | | 13 | | 15 | | |
| Loganathan, et al. 2009 | | | | | | 33 | | | | | | | | | | | 20 | | | | | |
| Patil, et al. 2007 | | | | | | | 27 | | | | | | | | | | | 21 | | | | |
| Qayum, et al. 2006 | | | | | 11 | 20 | 16 | | | | | | | | | 17 | 19 | 15 | | | | |
| Narayamoorthy, et al. 2006 | | | | | 24 | | | | | | | | | | | 16 | | | | | | |
| Gandhi, et al. 2006 | | | | | | 26 | | | | | | | | | | | 19 | | | | | |
| Morse, et al. 2005 | | | | 21 | 22 | | | | | | | | | | 15 | 14 | | | | | | |
| Pemsl, et al. 2004 | | | | 14 | | | | | | | | | | | 13 | | | | | | | |
| Orphal, J. 2005 | | | | 15 | | | | | | | | | | | 13 | | | | | | | |
| Bennet, et al. 2005 | | | | | 7 | | | | | | | | | | | 6 | | | | | | |
| Qaim, M. 2003 | | | 15 | | | | | | | | | | | 8 | | | | | | | | |
| Naik, G. 2001 | 18 | 8 | | | | | | | | | | 13 | 6 | | | | | | | | | |

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

Figure 4 depicts that overall results transgenic cotton in yield gain is relatively higher than its conventional. A little bit surprisingly [10], we found lower yield of transgenic cotton over non transgenic cotton assessed in 2003, and slightly different by scientists [11,12,13,14]. 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.

Another scientist who studied about farmers perception in Northern China found that farmers' main reasons for adopting Bt cotton was to save labor (97%), reduce pesticide application (91%), get high yield (88%) and grow cotton more profitably (85%) [15]. Whilst, [16] farmers opined in Karnataka found that there was a positive and significant impact of Bt cotton on their farm income by 94% and yield enhancement by 80% based on the farmers survey between 2007 and 2008. That is income gain is the main reason of farmers who willing to adopt transgenic cotton. Figure 5 reveals that the net return of Bt cotton is significantly different over non Bt cotton in India event its trend was not stable over time.

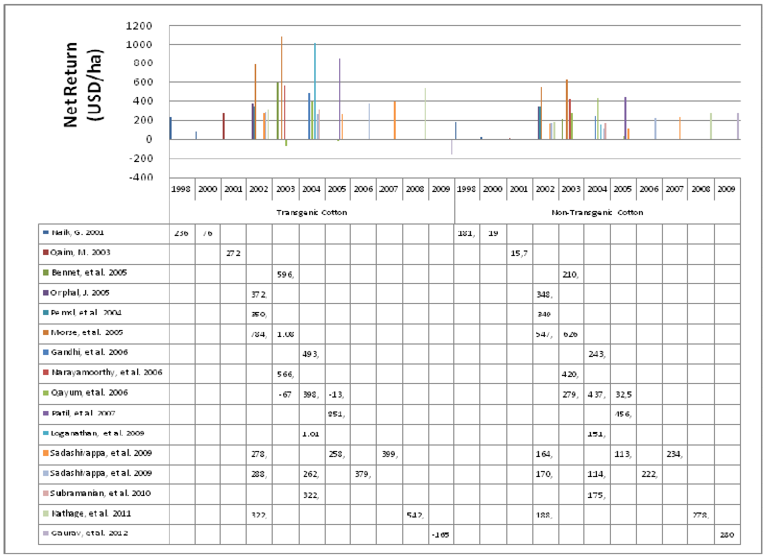



Figure 5. Net returns of Bt cotton over its counterpart across regions over time in India

Figure 5 reveals the highest net return in the year of 2004 (USD 1,014.7/ha) [9], and the lowest has been founded (USD -164.9/ha) in 2009 [11]. 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 seem to indicate that net return of Bt cotton is higher than non Bt cotton except study in Karnataka [13], [10] in Andhra Pradesh and [11] in Gujarat. Another found that higher profitability was the top most reason for choosing to grow Bt cotton [9]. 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.

The goal of state variety testing in the United States of America is to compare not only agronomic potential but also economic potential of commercially available cotton cultivars. Nowadays, in USA transgenic cotton cultivars have been developed and have been widely spread to provide growers with additional options for weed and insect control. Table 4 illustrates the economic indicator in terms of yield and net returns based on the database in comparison of using transgenic cotton cultivars including single gene and/or two gene cottons (B, B2R, B2RF, B2LL, W, WR, and WRF) and non-Bt cotton (R/RR, F/RF, LL and conventional variety).

Table 4 summarizes [17,18,19] reveal that non transgenic cotton was higher than transgenic cotton. In contrast, some of the authors through their study claimed that transgenic cotton is higher than its conventional. Study found that transgenic cotton was highly significant [20,21] suggest by using meta data, per-hectare returns obtained from transgenic cotton were found to be slightly higher than those obtained from non transgenic cotton. This is an high contrast [17,18,19] per-hectare non transgenic cotton was found to be generally higher than the returns per hectare from transgenic cotton. This meta data study provide the evidence of economic benefits which show that the economic value both transgenic and non transgenic cotton had varied across the regions in USA based on the field trials. Therefore, it is clear that this technology is not superior and still need to be suitable for the given production situation and also another factor that associated with market condition. And, also depending on the specific pest pressure and other relevant local condition to optimize per hectare returns. This study results that this merit technology can vary in different ecological environments.

Figure 6 illustrates the yield gains by using transgenic cotton and conventional cotton in USA over time. There was a significant yield by cultivating transgenic cotton as the highest yield gain [20] who had studied in the North Alabama during the period 2008-2009. Particularly in North Alabama and Alabama transgenic cotton yield was significantly different compare to its counterpart and also much higher compare to any other transgenic cotton among the regions in USA. However, [21] reported that transgenic cotton was slightly different compare to its conventional in any other county in Alabama.

Table 2. Meta data of yield gains and net returns based on the authors of database in China

| No. | Authors | Yield Gain (q/ha) Data Collection (Year) | | | | | | Net Return (USD/ha) Data Collection (Year) | | | | | | Location |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Sun, J., Huang, Qiao, F. 2000. | Trangenic | | | Non Transgenic | | | Trangenic | | | Non Transgenic | | | Shandong |
| | | 1999 | | | 1999 | | | 1999 | | | 1999 | | | |
| | | 33 | | | 32 | | | 130.2 | | | -310.4 | | | |
| 2. | Huang, J., Hu, R., Fan, C., Pray., Rozelle. 2002. | Transgenic | | | Non Transgenic | | | Transgenic | | | Non transgenic | | | Hebei, Shandong, Henan, Anhui, and Jiangsu |
| | | 1999 | 2000 | 2001 | 1999 | 2000 | 2001 | 1999 | 2000 | 20001 | 1999 | 2000 | 2001 | |
| | | 34 | 29 | 34 | 32 | 19 | 31 | 351 | 367 | 277 | -6 | -183 | -225 | |
| 3. | Huang, J.,Hu, R., Pray, C., Qiao, F., Rozelle, S. 2003. | Transgenic | | | Non Transgenic | | | Transgenic | | | Non Transgenic | | | Hebei and Shandong |
| | | 1999 | | | 1999 | | | 1999 | | | 1999 | | | |
| | | 33 | | | 32 | | | 156.2 | | | -270 | | | |
| 4. | Dong, H., Li, W., Tang, W., Zhang, D. 2004 | Transgenic | | | Non Transgenic | | | Transgenic | | | Non Transgenic | | | Shandong, Hebei, and Jiangsu |
| | | 2001 | 2002 | | 2001 | 2002 | | 2001 | 2002 | | 2001 | 2002 | | |
| | | 1.08 | 1.06 | | 1.02 | 1.0 | | 244.3 | 201.13 | | 167 | -15 | | |
| 5. | Xu, J.X, You, Z.B, Wang, W.Q, Yang, Y.Z. 2004 | Transgenic | | | Non Transgenic | | | Transgenic | | | Non Transgenic | | | Hebei |
| | | 2002 | 2003 | | 2002 | 2003 | | 2002 | 2003 | | 2002 | 2003 | | |
| | | 22 | 25 | | 13 | 15 | | 825.5 | 1,558.5 | | 355.9 | 978.8 | | |
| 6. | Fok, A.C.M., Xu, N. 2007 | Transgenic | | | Non Transgenic | | | Transgenic | | | Non Transgenic | | | Jiangsu |
| | | 2005 | | | 2005 | | | 2005 | | | 2005 | | | |
| | | 38 | | | 33 | | | 1,446.1 | | | 1,271.2 | | | |

Table 3. Meta data of yield gains and net returns based on the authors of database in India

| No. | Authors | Yield Gain (q/ha) Data Collection (Year) | | | | | | Net Return (USD/ha) Data Collection (Year) | | | | | | Location |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Transgenic** | | | **Non Transgenic** | | | **Trangenic** | | | **Non Transgenic** | | | |
| 1. | Naik, G. 2001 | 1998 | 2000 | | 1998 | 2000 | | 1998 | 2000 | | 1998 | 2000 | | Not available |
| | | 18 | 8 | | 13 | 6 | | 236 | 76 | | 181.7 | 19 | | |
| 2. | Qaim, M. 2003 | **Transgenic** | | | **Non Transgenic** | | | **Transgenic** | | | **Non Transgenic** | | | Central and Southern India |
| | | 2001 | | | 2001 | | | 2001 | | | 2001 | | | |
| | | 15 | | | 8 | | | 272 | | | 51.7 | | | |
| 3. | Bennet, Ismael, Morse. 2005 | **Transgenic** | | | **Non Transgenic** | | | **Transgenic** | | | **Non Transgenic** | | | Gujarat |
| | | 2003 | | | 2003 | | | 2003 | | | 2003 | | | |
| | | 7 | | | 6 | | | 596.3 | | | 210.7 | | | |
| 4. | Orphal J. 2005 | **Transgenic** | | | **Non Transgenic** | | | **Transgenic** | | | **Non Transgenic** | | | Karnataka |
| | | 2002 | | | 2002 | | | 2002 | | | 2002 | | | |
| | | 15 | | | 13 | | | 372.5 | | | 348.9 | | | |
| 5. | Pemsl, D., Waibel, H., Orphal, J. 2004 | **Transgenic** | | | **Non Transgenic** | | | **Transgenic** | | | **Non Transgenic** | | | Karnataka |
| | | 2002 | | | 2002 | | | 2002 | | | 2002 | | | |
| | | 14 | | | 13 | | | 350.1 | | | 349 | | | |
| 6. | Morse, S., Bennet, R.M., Ismael, Y. 2005. | **Transgenic** | | | **Non Transgenic** | | | **Transgenic** | | | **Non Transgenic** | | | Vidharba,Marathwada, Khandesh |
| | | 2002 | 2003 | | 2002 | 2003 | | 2002 | 2003 | | 2002 | 2003 | | |
| | | 21 | 22 | | 15 | 14 | | 784.7 | 1,083 | | 547.4 | 626 | | |
| 7. | Gandhi, P.V., Namboodiri, V.N. 2006 | **Transgenic** | | | **Non Transgenic** | | | **Transgenic** | | | **Non Transgenic** | | | Gujarat, Maharashtra, Andhra Pradesh, Tamil Nadu |
| | | 2004 | | | 2004 | | | 2004 | | | 2004 | | | |
| | | 26 | | | 19 | | | 493.2 | | | 243.1 | | | |
| 8. | Narayanamoorthy, A., Kalamkar, S. 2006 | **Transgenic** | | | **Non Transgenic** | | | **Transgenic** | | | **Non Transgenic** | | | Maharashtra |
| | | 2003 | | | 2003 | | | 2003 | | | 2003 | | | |
| | | 24 | | | 16 | | | 566.7 | | | 420.5 | | | |
| 9. | Qayum, A., Sakkhari, K. 2006. | **Transgenic** | | | **Non Transgenic** | | | **Transgenic** | | | **Non Transgenic** | | | Andhra Pradesh |
| | | 2003 | 2004 | 2005 | 2003 | 2004 | 2005 | 2003 | 2004 | 2005 | 2003 | 2004 | 2005 | |
| | | 11 | 20 | 16 | 17 | 19 | 15 | -67 | 398.7 | -13.7 | 279.8 | 437.9 | 32.5 | |
| 10. | Patil, B.V., M. | **Transgenic** | | | **Non Transgenic** | | | **Transgenic** | | | **Non Transgenic** | | | Not available |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Bheemanna, Hanchinal, S.G. 2007 | 2005 | | | 2005 | | | 2005 | | | 2005 | | | |
| | | 27 | | | 21 | | | 851.1 | | | 456.8 | | | |
| 11. | Loganathan, R., Balasubramanian, R., Mani, K., Gurunathan, S. 2009 | **Transgenic** | | | **Non Transgenic** | | | **Transgenic** | | | **Non Transgenic** | | | Tamil Nadu |
| | | 2004 | | | 2004 | | | 2004 | | | 2004 | | | |
| | | 33 | | | 20 | | | 1,014.7 | | | 151.7 | | | |
| 12. | Sadashivappa, P., Qaim, M. 2009a. | **Transgenic** | | | **Non Transgenic** | | | **Transgenic** | | | **Non Transgenic** | | | Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu |
| | | 2002 | 2005 | 2007 | 2002 | 2005 | 2007 | 2002 | 2005 | 2007 | 2002 | 2005 | 2007 | |
| | | 16 | 18 | 20 | 12 | 13 | 15 | 278.2 | 258.6 | 399.7 | 164.6 | 113.1 | 234.7 | |
| 13. | Sadashivappa, P., Qaim, M. 2009b. | **Transgenic** | | | **Non Transgenic** | | | **Transgenic** | | | **Non Transgenic** | | | Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu |
| | | 2002 | 2004 | 2006 | 2002 | 2004 | 2006 | 2002 | 2004 | 2006 | 2002 | 2004 | 2006 | |
| | | 16 | 18 | 20 | 12 | 13 | 14 | 288.2 | 262.1 | 379.2 | 170.6 | 114.6 | 222.6 | |
| 14. | Subramanian, A., Qaim, M. 2010 | **Transgenic** | | | **Non Transgenic** | | | **Transgenic** | | | **Non Transgenic** | | | Kanzara |
| | | 2004 | | | 2004 | | | 2004 | | | 2004 | | | |
| | | 18 | | | 13 | | | 322.1 | | | 175.8 | | | |
| 15. | Kathage, J., Qaim, M. 2011 | **Transgenic** | | | **Non Transgenic** | | | **Transgenic** | | | **Non Transgenic** | | | Central and Southern India, Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu |
| | | 2002 | 2008 | | 2002 | 2008 | | 2002 | 2008 | | 2002 | 2008 | | |
| | | 17 | 20 | | 13 | 14 | | 322.8 | 542.3 | | 188.9 | 278.9 | | |
| 16. | Gaurav, S., Mishra, S. 2012.. | **Transgenic** | | | **Non Transgenic** | | | **Transgenic** | | | **Non Transgenic** | | | Gujarat |
| | | 2009 | | | 2009 | | | 2009 | | | 2009 | | | |
| | | 30 | | | 29 | | | -164.9 | | | 280 | | | |

Table 4. Meta data of yield gains and net returns based on the authors of database in USA

| No. | Authors | Yield Gain (q/ha) Data Collection (Year) | | | | | | Net Return (USD/ha) Data Collection (Year) | | | | | | Location |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Transgenic | | | Non Transgenic | | | Trangenic | | | Non Transgenic | | | |
| 1. | Allen, T.C., Kharboutly, S.M., Bryant, K.J., Bourland, F.M., Earnest, L., Capps, C., Palmer G. 1999. | 1998 | | | 1998 | | | 1998 | | | 1998 | | | Arkansas |
| | | 9 | | | 11 | | | 1,067.2 | | | 1,267.5 | | | |
| 2. | Tingle, C., Studebaker, G., Greene, J., Bryant, K., Smith, K.L. 2001 | 2000 | | | 2000 | | | 2000 | | | 2000 | | | Arkansas |
| | | 11 | | | 10 | | | 860.8 | | | 803.6 | | | |
| 3. | Ward, C.W., White, F.C., Isengildina, O. 2001 | 1998 | | | 1998 | | | 1998 | | | 1998 | | | Georgia |
| | | 12 | | | 12 | | | 142.4 | | | 146.4 | | | |
| 4. | Bryant, et al 2002. | 1998 | | | 1998 | | | 1998 | | | 1998 | | | Arkansas |
| | | 9 | | | 10 | | | 780 | | | 929 | | | |
| 5. | Johnson, P.N., Blackshear, J. 2004. | 1998 | 1999 | 2000 | 1998 | 1999 | 2000 | 1998 | 1999 | 2000 | 1998 | 1999 | 2000 | Texas |
| | | 12 | 7 | 13 | 12 | 9 | 9 | 142.4 | 146 | 145.7 | 146.4 | 102.5 | 60.8 | |
| 6. | Boman, R., Kelley, M., stelter, M., 2005. | 2004 | | | 2004 | | | 2004 | | | 2004 | | | Texas |
| | | 20 | | | 26 | | | 736.9 | | | 1,150 | | | |
| 7. | Jost, P., Shurley, D., Culpepper, S., Roberts, P., Nochols, R., Reeves, J., Anthony, S. 2008 | 2001 | 2003 | 2004 | 2001 | 2003 | 2004 | 2001 | 2003 | 2004 | 2001 | 2003 | 2004 | Georgia |
| | | 11.3 | 12 | 13 | 11.5 | 12 | 11 | 1,402 | 1,885.1 | 1,710 | 1,478.5 | 1,730.1 | 1,274.8 | |
| 8. | Reed, T., Burmester, C.H., Monks, C.D. 2009 | 2008 | | | 2008 | | | 2008 | | | 2008 | | | Alabama |
| | | 22 | | | 16 | | | 2,165.3 | | | 1,556.1 | | | |
| 9. | Reed, T., Burmester, C.H., Schavey, E. 2010 | 2009 | | | 2009 | | | 2009 | | | 2009 | | | Alabama |
| | | 19 | | | 16 | | | 2,005.6 | | | 687.4 | | | |
| 10. | Patterson, M.G., Birdsong, W.C., Dillard, B.A., Mongks, C.D. 2012 | 2010 | 2011 | | 2010 | 2011 | | 2010 | 2011 | | 2010 | 2011 | | Alabama |
| | | 17 | 8 | | 15 | 7 | | 1,073 | 1,078 | | 949.2 | 736 | | |

Table 5. Meta data of yield gains and net returns based on the authors of database in Australia

| No. | Authors | Yield Gain (q/ha) | | | | | | | | | | Net Return (USD/ha) | | | | | | | | | | Location |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Data Collection (Year) | | | | | | | | | | Data Collection (Year) | | | | | | | | | | |
| | | Transgenic | | | | | Non Transgenic | | | | | Trangenic | | | | | Non Transgenic | | | | | |
| 1. | Fitt, G. 2003 | 1998 | 1999 | 2000 | 2001 | 2001 | 1998 | 1999 | 2000 | 2001 | 2001 | 1998 | 1999 | 2000 | 2001 | 2001 | 1998 | 1999 | 2000 | 2001 | 2001 | Northern Australia |
| | | 19 | 15 | 18 | 17 | 20 | 19 | 15 | 18 | 16 | 19 | | | | | | | | | | | |
| 2. | Pyke, B | 1998 | | | | | 1998 | | | | | 1998 | | | | | 1998 | | | | | Australia |
| | | 15 | | | | | 16 | | | | | | | | | | | | | | | |
| 3. | Doyle, et al. 2002 | 2001 | | | | | 2001 | | | | | 2001 | | | | | 2001 | | | | | New South Wales |
| | | 20 | | | | | 19 | | | | | | | | | | | | | | | |
| 4. | Hoque, et al 2000. | 1999 | | | | | 1999 | | | | | 1999 | | | | | 1999 | | | | | New South Wales |
| | | 18 | | | | | 17 | | | | | 2,023 | | | | | 1,800.3 | | | | | |
| 5. | Richards, D et al. 2007 | 2004 | | 2005 | | | 2004 | | 2005 | | | 2004 | | 2005 | | | 2004 | | 2005 | | | New South Wales |
| | | 18 | | 17 | | | 19 | | 17 | | | | | | | | | | | | | |
| 6. | Strickland, et al. 2005 | 2002 | | | | | 2002 | | | | | 2002 | | | | | 2002 | | | | | Not Available |
| | | 11 | | | | | 3 | | | | | 11 | | | | | 3 | | | | | |

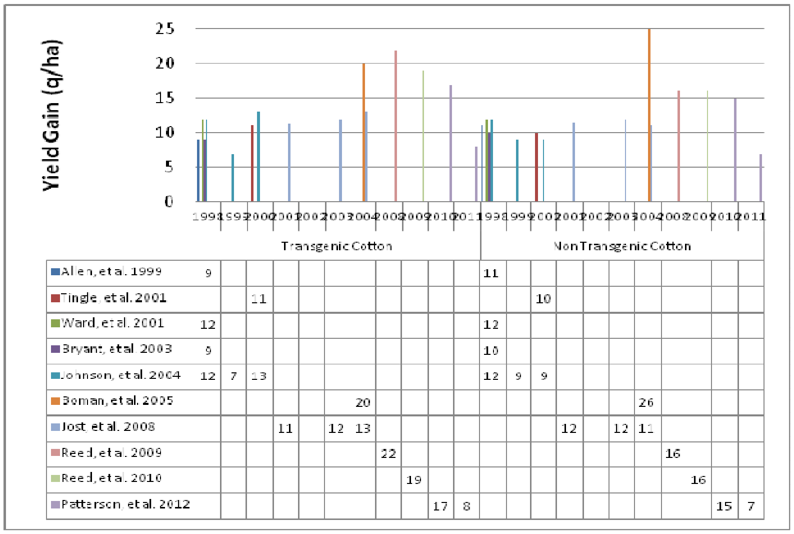



Figure 6. Yield Comparison between transgenic cotton and non-transgenic cotton in USA

Basically, Meta data found that yield comparison between transgenic and non transgenic cotton was not significantly different among the authors in USA except demonstrated by [20,22]. This is relevant that all varieties of transgenic cotton do not provide the same level of pest control [23]. Income gain is affected by seed cost, pesticide and herbicide cost, fertilizer, irrigation cost, labor and management cost and the other cost that affect income gain directly [23]

.

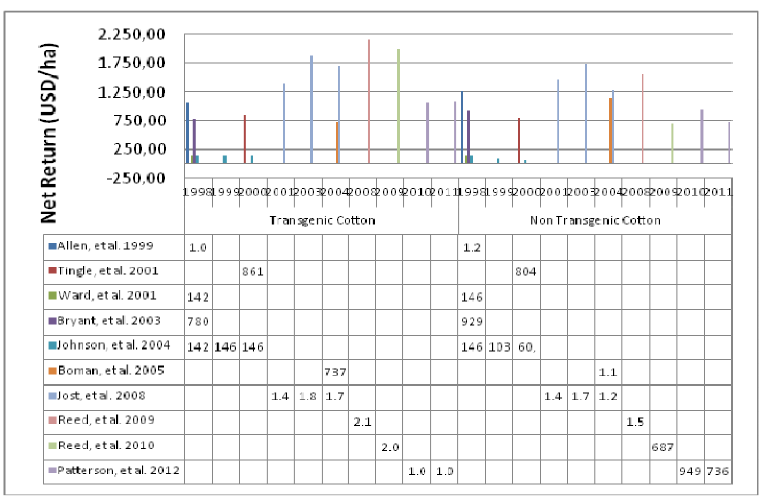



Figure 7. Yield Comparison between transgenic cotton and non-transgenic cotton in USA

Figure 7, in summary, study suggests that profit gain of the transgenic usage is not stable among the regions in USA. Some of regions provided that transgenic return was higher, whilst data represent that this technology had lower income than its counterpart. Specifically, conventional cotton still have good income in specific regions. Numerous studies of transgenic cotton performance are now available and mostly showing positive results. Many scientists through their publication claimed and promoted that transgenic cotton contribute to the economic gains. Counterfactual between transgenic cotton and its conventional provide the evidence whether both of them are stable or not over time. Given the comparison it is notable that the yields and economic benefit should have gain consistently. Higher yields and crop revenues are the main reason for the significant gains in cotton profits. It should be borne in mind that there are several methodological differences in the analysis of economic impact which could explain the spectrum of conclusions in the debate. Meta data presents the yield gain both Bt cotton and non-Bt cotton in any regions in Australia derived from many authors in Table 5.

Table 5 provides comprehensive details of all the data from different authors who had applied this technology in the field trials in some regions in Australia. Transgenic planting is generally higher than its conventional but it is not highly different. Some studies found that transgenic cotton is slightly higher [24,25,26,27] and another found that this transgenic cotton is lower than its counterpart [28]. However, [29] reported that Bt cotton was not different compare to its counterpart.

To sum up, the yield comparison between GM cotton and its counterpart was not significantly different based among the regions in Australia. This trends indicated that GM cotton production were fluctuating. This study suggest that transgenic cotton must be produced with best practice across a range of focus areas: land and water use, chemical use and integrated pest management, soil health, biodiversity, climate change and energy, technology and human resources.

## 4. CONCLUSION

Apart of this, a major effect of transgenic cotton in this study is a positive trend in yield advantage terms due to lower crop losses, reducing pesticide cost, and income gain. Thus, explain the adoption of transgenic cotton. But the study also underlines, through meta data analysis with the various results and reasons above, that such outcomes cannot be generalized across the countries in the global area.

## REFERENCES


1. Anderson, K., Valenzuela, E.and Jackson, A.L. GM cotton adoption, recent and prospective: A global CGE analysis of economic impcats. World Bank's projects on Agricultural Trade Reform and the Doha Development Agenda and GMOs, Trade and Developing Countries. 2006.

2. Morse, S and Mannion, A.M. Genetically Modified cotton and sustainability. Geogrsphicsl paper No. 184. Department of geography school of Human and Environmental Sciences University of Reading Whitekinights, Reading, Bershire RG66AB. 2008.

3. Huang, J., Mi, J., Lin, H., Wang, Z.J., Chen, R., Hu, R., Rozelle, and S., Pray, C., A decade of Bt cotton in Chinese fields: Assessing the direct effects and indirect externalities of Bt cotton adoption in China. Chinese press. 58p. 2010.

4. Dong, H., Li, W., Tang, W. And Zhang. Develpment of Hybrid Bt cotton in China-A succesful integration of transgenic technology and conventional techniques. Current Science. 2004;86:778-782.

5. Sun, J., Huang, and Qiao, F. An economic analysis of Bt cotton benefit. Journal of Agro-Economic. 2000;3(7):15-19. (in Chinese). China Academic Journal Electronic Publishing House. http://www.enki.net

6. Huang, J., Hu, R., Pray, C.E., Qiao, F., and Rozelle, S. Biotechnology as an alternative to chemical pesticide: a case study of Bt cotton in China. Agricultural economics.2003;29:55-67

7. Xu, J.X, You, Z.B, Wang, W.Q, and Yang, Y.Z. An economic analysis of Bt cotton planting in Jiangsu. Journal of Yangzhou University. Agricultural and Life-Science Edition. 2004;25 (3): 65-69 (in Chinese).

8. Fok, A.C.M., and Xu, N. Multiple factor adoption of GM cotton in China: Influence of conventional technology development and rural change in Jiangsu Province. World cotton research conference, 10-14 September. p.114. 2007.

9. Loganathan, R., Balasubramanian, R., Mani, K., and Gurunathan, S. Productivity and profitability impact of genetically modified crops-An economic analysis of Bt cotton cultivation in Tamil Nadu. Agricultural Economics Research Review. 2009;22(3):331-340.

10. Qayum, A. and Sakkhari, K. Bt cotton in Andhra Pradesh. A three-year assessment. The first ever sustained independent scientific study of Bt cotton in India. Report from Deccan Development Society, Andhra Pradesh Coalition in Defence of Diversity, Permaculture Association of India. 25p. (2006).

11. Gauraf, S., and Mishra, S. Paper presented in the National Seminar, Gujarat Institute of Development Research. Indira Gandhi Institute of Development Research, Mumbai. 72p. 2012.

12. Pemsl, D., Waibel, H., Orphal, J. A methodology to assess the profitability of Bt cotton: case study results from the state of Karnataka, India. Journal of Crop protection. 2004;23: 1294-1257.

13. Orphal, J.. Comparative analysis of the economics of Bt and non-Bt cotton production. Pesticide Policy Project Series, No. 8, 2008. Institute of Economics in Horticulture, Faculty of Business Admisntration and Economics. University of Hannover, Germany. 12p. 2005.

14. Bennet, R., Ismael, Y. and Morse, S.,. Explaning contradictory evidence regarding impacts of genetically modified crops in developing countries. Varietal performance of transgenic cotton in India. Journal of Agricultural Science. 2005;143(1):35-41

15. Yang, P., Iles, M., Yan, S., and Jolliffe, F. Farmers' knowledge, perceptions, and practices in transgenic Bt cotton in small producer system in Northern China. Crop Protection. 2005; 24: 229-239.

16. Kiresur, V.R. and Ichangi, M. Socio-economic impact of Bt cotton. A case study of Karnataka. Agricultural Economic Research Review. 2011;24:67-81.

17. Allen, T.C., Kharboutly, S.M., Bryant, K.J., Bourland, F.M., Earnest, L., Capps, C. and Palmer G. Transgenic and conventional insect and weed control systems. Proceedings of the 1999 Cotton Research Meeting and Summaries of Cotton Research in Progress. Special Report 193. Arkansas Agricultural Experiment Station. Division of Agriculture, University of Arkansas. p232-235 .

18. Bryant, K., Greene, J.K., Capps, C.D., Groves, F.E., Tingle, C., Studebaker, G., Bourland, F.M., Nichols, B. and Reeves, J. An economic comparison of transgenic and non transgenic cotton production system in Arkansas. Cotton research meeting and summaries of research in progress. Arkansas Agriculture Experiment Station Research Series 521, p.255-260. 2003.

19. Jost, P., Shurley, D., Culpepper, S., Roberts, P., Nichols, R., Reeves, J., and Anthony, S. Economic comparison of transgenic and non transgenic cotton production systems in Georgia. Agronomy Journal. 2008;100(1):42-51.

20. Reed, T., Burmester, C.H., and Monks, C.D. Economic consequences of using different cotton variety technology system in Alabama. Cotton Research Report No.33. March 2009. Alabama Agricultural Experiment Station. Auburn University. 17p. 2009.

21. Patterson, M.G., Birdsong, W.C., Dillard, B.A., and Mongks, C.D. Economic comparison of LibertyLink, Roundup Ready Flex, and conventional systems for resistant pigweed management in Alabama cotton. Cotton Research Report No.41 March 2012. Alabama Agricultural Experiment Station. Auburn University. p14. 2012.

22. Reed, T., Burmester, C.H., Schavey, E. Economic consequences of using different cotton variety technology systems in North Alabama. Cotton Research

Report No.33. March 2009. Alabama Agricultural Experiment Station. Auburn University. 25p. 2010.

23. Adamczyk, J. and Sumerford, D.. Potential factors impacting season-long expression of Cry1Ac in 13 commercial varieties of Bollgard cotton. Journal of Insect Science. 2001;1(13): 1-6.

24. Doyle, B., I. Reeve, and K. Bock. The performance of INGARD cotton in Australia in the 2001/2002 season. A Report Prepared for the Cotton Research and Development Corporation on behalf of Cotton Consultants Australia Inc. 72p. 2002.

25. Hoque, Z., Farquharson, B., Dillon, and M., Kauter, G.. An economic assessment of insecticide resistance management strategies in the Australian cotton industry.. Paper presented to the 44 Annual Conference of the Australian Agricultural and Resources Economics Society Inc. The University of Sidney. p.15. 2000.

26. Richards, D., Yeates, S., Roberts, G. and Gregory, R. Does Bollgard II cotton use more water ? Paper presented to the 44 Annual Conference of the Australian Agricultural and Resource Economic Society. p13. 2007.

27. Strickland, GR. and Annels, AJ. The seasonal dynamics of arthropods in conventional, INGARD and Bollgard II cotton genotypes in a winter production system at Kununurra. Research paper. Department of Agriculture. Locked Bag 4. Bentley Delivery Centre WA 6983. 2005.

28. Pyke, B. The performance of INGARD® cotton in Australia in the 1998/99 season. Cotton R&D Corporation Occasional Paper. 46p. 1999.

29. Fitt, G. P. Implementation and impact of transgenic Bt cottons in Australia. p.1778. *Cotton Production for the New Millennium. Proceedings of the third World Cotton Research Conference*, 9-13 March, Cape Town, South Africa.. Agricultural Research Council - Institute for Industrial Crops, Pretoria, South Africa. 2003.