GM Crops & Food ›
Biotechnology in Agriculture and the Food Chain
Volume 9, 2018 - Issue 2

Research Paper

Farm income and production impacts of using GM crop technology 1996–2016

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Pages 59-89 | Received 15 Feb 2018, Accepted 05 Apr 2018, Published online: 11 Jun 2018

Cite this article https://doi.org/10.1080/21645698.2018.1464866 Check for updates

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example, added 213 million tonnes and 405 million tonnes respectively, to the global production of soybeans and maize since the introduction of the technology in the mid 1990s.

KEYWORDS: yield cost income production genetically modified crops

INTRODUCTION

2016 represents the twenty first year of widespread cultivation of crops containing genetically modified (GM) traits, with our estimate of the global planted area of GM-traited crops in this year to be about 178 million hectares.

During this period, there have been many papers assessing the farm level economic and farm income impacts associated with the adoption of this technology. The authors of this paper have, since 2005, engaged in an annual exercise to aggregate and update the sum of these various studies, and where possible to supplement this with new analysis. The aim of this has been to provide an up to date and as accurate as possible assessment of some of the key farm level economic impacts associated with the global adoption of crops containing GM traits. It is also hoped the analysis continues to contribu ... facilitate more inf ... nology is currently ...

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The analysis concentrates on gross farm income effects because these are a primary driver of adoption amongst farmers (both large commercial and small-scale subsistence). It also quantifies the (net) production impact of the technology. The authors recognise that an economic assessment could examine a broader range of potential impacts (eg, on labour usage, household incomes, local communities and economies).

However, these are not included because undertaking such an exercise would add considerably to the length of the paper and an assessment of wider economic impacts would probably merit a separate assessment in its own right.

RESULTS AND DISCUSSION

a Herbicide Tolerant (HT) Crops

The main impact of GM HT (largely tolerant to the broad-spectrum herbicide glyphosate) technology has been to provide more cost effective (less expensive) and easier weed control for farmers. Nevertheless, some users of this technology have also derived higher yields from better weed control (relative to weed control obtained from conventional technology). The magnitude of these impacts varies by country and year, and is m … systems versus c … d, the cost farmers … ms. The following … ecent years should b …

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from it. In addition, it is influenced by intellectual property rights (patent protection, plant breeders' rights and rules relating to use of farm-saved seed). In countries with weaker intellectual property rights, the cost of the technology tends to be lower than in countries where there are stronger rights. This is examined further in c) below;

- Where GM HT crops (tolerant to glyphosate) have been widely grown, some incidence of weed resistance to glyphosate has occurred and resistance has become a major concern in some regions. This has been attributed to how glyphosate was used; because of its broad-spectrum post-emergence activity, it was often used as the sole method of weed control. This approach to weed control put tremendous selection pressure on weeds and as a result contributed to the evolution of weed populations predominated by resistant individual weeds. It should, however, be noted that there are hundreds of resistant weed species confirmed in the International Survey of Herbicide Resistant Weeds (www.weedscience.com)[76]. Worldwide, there are 41 weed species that are currently resistant to glyphosate (accessed February 2018), compared to 160 weed species resistant to ALS herbicides (eg, chlorimuron ethyl commonly used in conventional soybean crops) and 74 weed species resistant to photosystem II inhibitor herbicides (eg, atriazine commonly used in corn production). In addition, GM HT technology has played a major role in facilitating the adoption of no and reduced tillage
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the form of lower costs of production or higher yields (arising from better weed control). It should also be noted that many of the herbicides used in conventional production systems had significant resistance issues themselves in the mid 1990s and this was one of the reasons why glyphosate tolerant soybeans were rapidly adopted, as glyphosate provided good control of these weeds. If the GM HT technology was no longer delivering net economic benefits, it is likely that farmers around the world would have significantly reduced their adoption of this technology in favour of conventional alternatives. The fact that GM HT global crop adoption levels have not fallen in recent years suggests that farmers must be continuing to derive important economic benefits from using the technology.

These points are further illustrated in the analysis below.

GM HT soybeans

The impact of this technology on gross farm income is summarised in Table 1. The main farm level gain has arisen from a reduction in the cost of production, mainly through lower expenditure on weed control (mostly herbicides). Not surprisingly, where yield gains have occurred from improvements in the level of weed control, the average farm income gain has been higher, in countries such as Romania, Mexico and Bolivia. A second generation of GM HT soybeans became available to commercial soybean growers … tolerance to glyphos… er yielding potentia… oss farm income … on of no tillage p… has enabled … iately after a wheat … aditional 'one … d to the volu… y.

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Overall, in 2016, GM HT technology in soybeans (excluding second generation 'Intacta' soybeans: see below) has boosted gross farm incomes by $4.37 billion, and since 1996 has delivered $54.6 billion of extra farm income. Of the total cumulative farm income gains from using GM HT soybeans, $24.6 billion (45%) has been due to yield gains/second crop benefits and the balance, 55%, has been due to cost savings.

GM HT and IR (intacta) soybeans

This combination of GM herbicide tolerance (to glyphosate) and insect resistance in soybeans was first grown commercially in 2013, in South America. In the first four years, the technology was used on approximately 49.6 million hectares and contributed an additional $5.2 billion to gross farm income of soybean farmers in Argentina, Brazil, Paraguay and Uruguay, through a combination of cost savings (decreased expenditure on herbicides and insecticides) and higher yields (see Table 1).

GM HT maize

The adoption of GM HT maize has mainly resulted in lower costs of production, although yield gains from improved weed control have arisen in Argentina, Brazil, the Philippines and Vietnam (Table 2).

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savings (71% of the total gains), although there have been some yield gains in Argentina, Brazil, Mexico and Colombia (Table 3).

TABLE 3. GM HT cotton summary of average gross farm income impacts 1996–2016 ($/hectare).

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Other HT crops

GM HT canola (tolerant to glyphosate or glufosinate) has been grown in Canada, the US, and more recently Australia, whilst GM HT sugar beet is grown in the US and Canada. The gross farm income impacts associated with the adoption of these technologies are summarised in Table 4. In both cases, the main farm income benefit has derived from yield gains. In 2016, the total global income gain from the adoption of GM HT technology in canola and sugar beet was $559 million and cumulatively since 1996, it was $6.44 billion.

TABLE 4. Other GM HT crops summary of average gross farm incom

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The greatest improvement in yields has occurred in developing countries, where conventional methods of pest control have been least effective (eg, reasons such as poorly developed extension and advisory services, lack of access to finance to fund use of crop protection application equipment and products), with any cost savings associated with reduced insecticide use being mostly found in developed countries. These effects can be seen in the level of farm income gains that have arisen from the adoption of these technologies, as shown in

TABLE 6. GM IR crops: Average gross farm income benefit 1996–2016 ($/hectare).

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Table 6.

At the aggregate level, the global gross farm income gains from using GM IR maize and cotton in 2016 were $4.81 billion and $3.7 billion respectively. Cumulatively since 1996, the gains have been $50.6 billion for GM IR maize and $54 billion for GM IR cotton.

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value of global production of the four main crops of soybeans, maize, canola and cotton. Since 1996, gross farm incomes have increased by $186.1 billion.

At the country level, US farmers have been the largest beneficiaries of higher incomes, realising over $80.3 billion in extra income between 1996 and 2016. This is not surprising given that US farmers were first to make widespread use of GM crop technology and for many years the GM adoption levels in all four US crops have been in excess of 80%. Important farm income benefits ($46.4 billion) have occurred in South America (Argentina, Bolivia, Brazil, Colombia, Paraguay and Uruguay), mostly from GM technology in soybeans and maize. GM IR cotton has also been responsible for an additional $40.8 billion additional income for cotton farmers in China and India.

In 2016, 55% of the farm income benefits were earned by farmers in developing countries. The vast majority of these gains have been from GM IR cotton and GM HT soybeans. Over the twenty-one years 1996–2016, the cumulative farm income gain derived by developing country farmers was $96 billion, equal to 51.7% of the total farm income during this period.

The cost to farmers for accessing GM technology, across the four main crops, in 2016, was equal to 29% of the total value of technology gains. This is defined as the farm income gains referred to above plus the cost of the technology payable to the seed supply chain. Readers should note that the cost of the technology accrues to the seed supply c … eeders, distribut …

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savings is changing as second-generation GM crops are increasingly adopted. Thus in 2016 the split of total income gain came 72% from yield/production gains and 28% from cost savings.

Crop production effects

Based on the yield impacts used in the direct farm income benefit calculations above and taking account of the second soybean crop facilitation in South America, GM crops have added important volumes to global production of maize, cotton, canola and soybeans since 1996 (Table 7).

TABLE 7. Additional crop production arising from positive yield effects of GM crops.

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The GM IR traits, used in maize and cotton, have accounted for 93.5% of the additional maize production and 98.9% of the additional cotton production. Positive yield impacts from the use of this technology have occurred in all user countries, except for GM IR cotton in Australia where the levels of Heliothis sp (boll and bud worm pests) pest control p [illegible] he main benefit a [illegible] om significa [illegible] ed insectici [illegible] conventi [illegible] ments). The average [illegible] 1 years since 19

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CONCLUDING COMMENTS

In the last 21 years, crop biotechnology has helped farmers grow more food using fewer resources by reducing the damage caused by pests and better controlling weeds. The highest yield increases have occurred in developing countries and this has contributed to a more reliable and secure food supply base in these countries. In South America, HT technology has helped farmers reduce tillage, shortening the time between planting and harvesting, allowing them the opportunity to grow an additional soybean crop after wheat in the same growing season.

With higher yields and less time and money spent managing pests and weeds, farmers have earned higher incomes. This has proved to be especially valuable for farmers in developing countries where, in 2016, an average $5 was received for each extra dollar invested in biotech crop seeds.

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Neverth … glyphosate and the … contributed to th … d maintain good lev … rated weed manage … nd cultural weed co … ate rather than sol … r herbicides, such as … added cost to the G … ough relative to the current conventional alternative, the GM HT technology continues to offer important economic benefits in 2016.

Overall, there continues to be a considerable and growing body of evidence, in peer reviewed literature, and summarised in this paper, that quantifies the positive economic impacts of crop biotechnology. The analysis provides insights into the reasons why so many farmers around the world have adopted and continue to use the technology. Readers are encouraged to read the peer reviewed papers cited, and the many others who have published on this subject (and listed in the references below) and to draw their own conclusions.

METHODOLOGY

The report is based on detailed analysis of existing farm level impact data for GM crops, much of which can be found in peer reviewed literature. Most of this literature broadly refers to itself as 'economic impact' literature and applies farm accounting or partial budget approaches to assess the impact of GM crop technology on revenue, key costs of production (notably cost of seed, weed control, pest control and use of labour) and gross farm income. Whilst primary data for impacts of commercial cultivation were not available for every crop, in every year and for each country, a substantial body of

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unrepresentative samples of cotton farmers. Only the reasonably representative research has been drawn on for use in this paper – readers should consult the references to this paper to identify the sources used.

This approach may still both, overstate, or understate, the impact of GM technology for some trait, crop and country combinations, especially in cases where the technology has provided yield enhancements. However, as impact data for every trait, crop, location and year data is not available, the authors have had to extrapolate available impact data from identified studies to years for which no data are available. In addition, if the only studies available took place several years ago, there is a risk that basing current assessments on such comparisons may not adequately reflect the nature of currently available alternative (non-GM seed or crop protection) technology. The authors acknowledge that these factors represent potential methodological weaknesses. To reduce the possibilities of over/understating impact due to these factors, the analysis:

- Directly applies impacts identified from the literature to the years that have been studied. As a result, the impacts used vary in many cases according to the findings of literature covering different years. Examples where such data is available include the impact of GM insect resistant (IR) cotton: in India (see Bennett R et al,[4] IMRB[5] and IMRB[6]), in Mexico (see Traxler and Godoy-Avila[75] and Monsanto Mexico annual monit … in the US (see S … es into accou … s effecti … tation levels;

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- Adjusts downwards the average base yield (in cases where GM technology has been identified as having delivered yield improvements) on which the yield enhancement has been applied. In this way, the impact on total production is not overstated.

Detailed examples of how the methodology has been applied to calculate the 2016 impacts are presented in Appendix 1.

Other aspects of the methodology used to estimate the impact on direct farm income are as follows:

- Where stacked traits have been used, the individual trait components were analysed separately to ensure estimates of all traits were calculated. This is possible because the non-stacked seed has been (and in many cases continues to be) available and used by farmers and there are studies that have assessed trait-specific impacts;

- All values presented are nominal for the year shown and the base currency used is the US dollar. All financial impacts in other currencies have been converted to US dollars at prevailing annual average exchange rates for each year (source: United States Department of Agriculture Economics Research Service);

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The paper also includes estimates of the production impacts of GM technology at the crop level. These have been aggregated to provide the reader with a global perspective of the broader production impact of the technology. These impacts derive from the yield impacts and the facilitation of additional cropping within a season (notably in relation to soybeans in South America). Details of how these values were calculateed (for 2016) are shown in Appendix 1.

ACKNOWLEDGEMENTS

The authors acknowledge that funding towards the researching of this paper was provided by Monsanto. The material presented in this paper is, however, the independent views of the authors – it is a standard condition for all work undertaken by PG Economics that all reports are independently and objectively compiled without influence from funding sponsors.

Additional information

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Monsant

REF

1. Brook ... rop techn ... doi:10

2. Norsw ... Bradley

best management practices and recommendations. Weed Sci. 2012, Herbicide Resistant Weeds Special Issue, 60:31–62. doi:10.1614/WS-D-11-00155.1.
Web of Science ® | Google Scholar

3. Monsanto US. Field trials network in the Western Great Plains. https://monsanto.com/products/learning-centers/gothenburg-learning-center/.
Google Scholar

4. Bennett R, Ismael Y, Kambhampati U, Morse S. Economic impacts of GM cotton in India. AgBioforum. 2004;7(3):96–100.
Google Scholar

5. IMRB. Socio-economic benefits of Bollgard and product satisfaction (in India). Mumbai, India: IMRB International; 2006.
Google Scholar

6. IMRB. Socio-economic benefits of Bollgard and product satisfaction (in India). Mumbai, India: IMRB International; 2007.
Google Scholar

7. Sanka ... ved crops plante ... 003.
www.r
Goog

8. Sanka ... ved crops plante ... gton.
ww
Go

9. Mullin ... parisons. 2004 I
Goog

10. Brookes G. The farm level impact of using Roundup Ready soybeans in Romania. Agbioforum. 2005;8(4):235–41. www.agbioforum.org.

Google Scholar

11. Monsanto Romania. Unpublished results of farmer survey amongst soybean growers in 2006 – published in 2007.

Google Scholar

12. Qaim M, Traxler G. Roundup Ready soybeans in Argentina: farm level & aggregate welfare effects. Agric Econ. 2005;32(1):73–86. doi:10.1111/j.0169-5150.2005.00006.x.

Web of Science ® | Google Scholar

13. Trigo E, Cap E. Ten years of GM crops in Argentine Agriculture, ArgenBio. 2006. http://argenbio.org/biblioteca/Ten_Years_of_GM_Crops_in_Argentine_Agriculture_02_01_07.pdf

.

Google Scholar

14. Parana Department of Agriculture. Cost of production comparison: biotech and conve ... ber 2004.

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Goog

15. Galve ... bicide

tolera

Goog

16. Ga ... eres, Brazil.

www.c

Goog

17. Galve ... eres, Brazil.

www.c

Goog

18. Marra M, Pardey P, Alston J. The pay-offs of agricultural biotechnology: an assessment of the evidence, 2002, International Food Policy Research Institute, Washington, USA.
Google Scholar

19. Carpenter J, Gianessi L. Agricultural Biotechnology: updated benefit estimates. Washington, USA: National Centre for Food and Agricultural Policy (NCFAP); 2002.
Google Scholar

20. Johnson S, Strom S. Quantification of the impacts on US agriculture of biotechnology-derived crops planted in 2006, 2008. NCFAP, Washington. www.ncfap.org.
Google Scholar

21. George Morris Centre. Economic & environmental impacts of the commercial cultivation of glyphosate tolerant soybeans in Ontario. 2004, unpublished report for Monsanto Canada.
Google Scholar

22. AMIS Global/Kleffmann. Subscription-based data sources (derived from farmer surveys) on pesticide use. Kleffmann Gmbh, Ludinghausen, Germany. www.kleffmann.com.
Goog

23. Fernar 9, paper
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24. MB Ag the new
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25. Mende n cost
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Article contents Related research

26. Gonsales L. Modern Biotechnology and Agriculture: a history of the commercialisation of biotechnology maize in the Philippines. Los Banos, Philippines: Strive Foundation; 2009. ISBN:978-971-91904-8-6.
Google Scholar

27. Brookes G. The potential socio-economic and environmental impacts from adoption of corn hybrids with biotech trait/technologies in Vietnam. 2017. PG Economics, UK. www.pgeconomics.co.uk.
Google Scholar

28. Doyle B. The Performance of Roundup Ready cotton 2001–2002 in the Australian cotton sector. Armidale, Australia: University of New England; 2003.
Google Scholar

29. Canola Council of Canada. An agronomic & economic assessment of transgenic canola. 2001, Canola Council, Canada. www.canola-council.org.
Google Scholar

30. Gusta M, Smyth S, Belcher K, Phillips P, Castle D. Economic benefits of GM HT canola for producers. AgBioForum. 2011;14(1):1–12.
Goog

31. Monsa 008.
Goog

32. Fische f Roundup
Ready rtin
Un
Go

33. Hudso and co-
existe 10–2012.
Agbio
Goog

Article contents Related research

34. Kniss A. Comparison of conventional and glyphosate resistant sugarbeet the year of commercial introduction in Wyoming. J Sugar Beet Res. 2010;47:127–34. doi:10.5274/jsbr.47.3.127.
Google Scholar

35. Khan M. Roundup Ready sugar beet in America. Br Sugar Beet Rev Winter. 2008;76(4):16–9.
Google Scholar

36. Jon-Joseph AQ, Sprague CL. Weed management in wide-and narrow-row glyphosate resistant sugar beet. Weed Technol. 2010;24:523–8. doi:10.1614/WT-D-10-00033.1.
Web of Science ® | Google Scholar

37. Hutchison W, Burkness EC, Mitchel PD, Moon RD, Leslie TW, Fleicher SJ, Abrahamson M, Hamilton KL, Steffey KL, Gray ME, et al. Area-wide suppression of European Corn Borer with Bt maize reaps savings to non-bt maize growers. Science. 2010;330:222–5. www.sciencemag.org. doi:10.1126/science.1190242. PMID:20929774.
PubMed | Web of Science ® | Google Scholar

38. Rice M. Transgenic rootworm corn: assessing potential agronomic, economic and enviro
Goog

39. Pray C … nefits
contin … 01.x.
PMID:

40. Gous … Africa: the
case c
doi:10

41. Gouse … mum tillage

Google Scholar

42. Gouse M, Pray C, Kirsten J, Schimmelpfennig D. Three seasons of insect resistant maize in South Africa: have small farmers benefited. AgBioforum. 2006;9(1):15–22.
Google Scholar

43. Van der Weld W. Final report on the adoption of GM maize in South Africa for the 2008/09 season, South African Maize Trust, 2009.
Google Scholar

44. Ismael Y, Bennet R, Morse S. Benefits of bt cotton use by smallholder farmers in South Africa. Agbioforum. 2002;5(1):1–5.
Google Scholar

45. Kirsten J, Gouse M. Bt cotton in South Africa: adoption and the impact on farm incomes amongst small-scale and large-scale farmers. ICABR conference, Ravello, Italy, 2002.
Google Scholar

46. James C. Global review of commercialized transgenic crops 2002: feature Bt maize. ISAAA
Goog

47. Falck Z … all 'resource
poor' … : the case of
insect … esented to
the 13
G

48. Falck Z … ught
betwe … doption of
GM m
Goog

49. Trigo E. Genetically Modified Crops in Argentina agriculture: an opened story. Buenos Aires, Argentina: Libros del Zorzal; 2002.
Google Scholar

50. Qaim M, De Janvry A. Bt cotton in Argentina: analysing adoption and farmers' willingness to pay. 2002, American Agricultural Economics Association Annual Meeting, California.
Google Scholar

51. Qaim M, De Janvry A. Bt cotton and pesticide use in Argentina: economic and environmental effects. Environ Dev Econ. 2005;10:179–200. doi:10.1017/S1355770X04001883.
Web of Science ® | Google Scholar

52. Elena M. Economic advantages of transgenic cotton in Argentina, INTA. 2006, cited in Trigo and CAP 2006.
Google Scholar

53. Gonsales L. Harnessing the benefits of biotechnology: the case of Bt corn in the Philippines. ISBN 971-91904-6-9. Laguna, Philippines: Strive Foundation; 2005.
Goog

54. Yorobe ... sented to the
45th F
Goog

55. Ramo ... ce
m ... nes (BCP);
20
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56. Brook ... rence paper
2003,
Goog

57. Brookes G. The benefits of adopting GM insect resistant (Bt) maize in the EU: first results from 1998–2006. Int J Biotechnol. 2008;10(2/3):148–66. doi:10.1504/IJBT.2008.018351.
Google Scholar

58. Gomez-Barbero M, Barbel J, Rodriguez-Cerezo E. Adoption and performance of the first GM crop in EU agriculture: Bt maize in Spain. 2008. JRC, EU Commission. Eur 22778. http://www.jrc.ec.europa.eu.
Google Scholar

59. Riesgo L, Areal F, Rodriguez-Cerezo E. How can specific market demand for non-GM maize affect the profitability of Bt and conventional maize? A case study for the middle Ebro Valley, Spain. Spanish J Agric Res. 2012;10(4):867–76. doi:10.5424/sjar/2012104-448-11.
Web of Science ® | Google Scholar

60. Herring R, Rao C. On the ‘failure of Bt cotton’: analysing a decade of experience. Econ Polit Wkly. 2012;47(18):5/5/2012.
Google Scholar

61. Zamb … er presented to the …
Goog…

62. Vitale … eration Bt cotton … nol. 2008;…

63. Vitale … f Small… vey14th ICABR…
Goog…

54. Galveo A. Unpublished data on first survey findings of impact of insect resistant corn (first crop) in Brazil, 2009, Celeres, Brazil. www.celeres.co.br.
Google Scholar

55. Monsanto Brazil. Farm survey of conventional and Bt cotton growers in Brazil 2007. unpublished.
Google Scholar

56. Nazli H, Sarker R, Meilke K, Orden D. Economic performance of Bt cotton varieties in Pakistan. Conference paper at the Agricultural and Applied Economics Association 2010 AAEA, CAES and WACA Joint Annual Meeting, Denver, USA.
Google Scholar

57. Kouser S, Qaim M. Valuing financial, health and environmental benefits of Bt cotton in Pakistan. Agric Econ. 2013;44:323–35. doi:10.1111/agec.12014.
Web of Science ® | Google Scholar

58. Kouser S, Qaim M. Bt cotton, damage control and optimal levels of pesticide use in Pakistan. Environ Dev Econ. 2014;19(06):704–23. doi:10.1017/S1355770X1300051X.
Web of Science ® | Google Scholar

59. USDA. ... 0025 of 14th
Januar...
Goog...

70. Doyle ... ring the
2002/... w England;
20...
Goo...

71. James ... Bt cotton.
ISAAA...
Goog...

Article contents | Related research

72. CSIRO. The cotton consultants Australia 2005 Bollgard II comparison report, CSIRO, Australia.
Google Scholar

73. Fitt G. Deployment and impact of transgenic Bt cotton in Australia, reported in James C (2001), Global review of commercialised transgenic crops: 2001 feature: Bt cotton, ISAAA.
Google Scholar

74. Monsanto Comercial Mexico. Official reports to Mexican Ministry of Agriculture of the (year) cotton crop, unpublished papers for 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016.
Google Scholar

75. Traxler G, Godoy-Avila S. Transgenic cotton in Mexico. Agbioforum. 2004;7(1&2):57–62.
Google Scholar

76. Weedscience.org. Website of International Survey of Herbicide Resistant Weeds. www.weedscience.org.
Goog