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INTERNATIONAL SERVICE
FOR THE ACQUISITION
OF AGRI-BIOTECH
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ISAAA Briefs

BRIEF 44

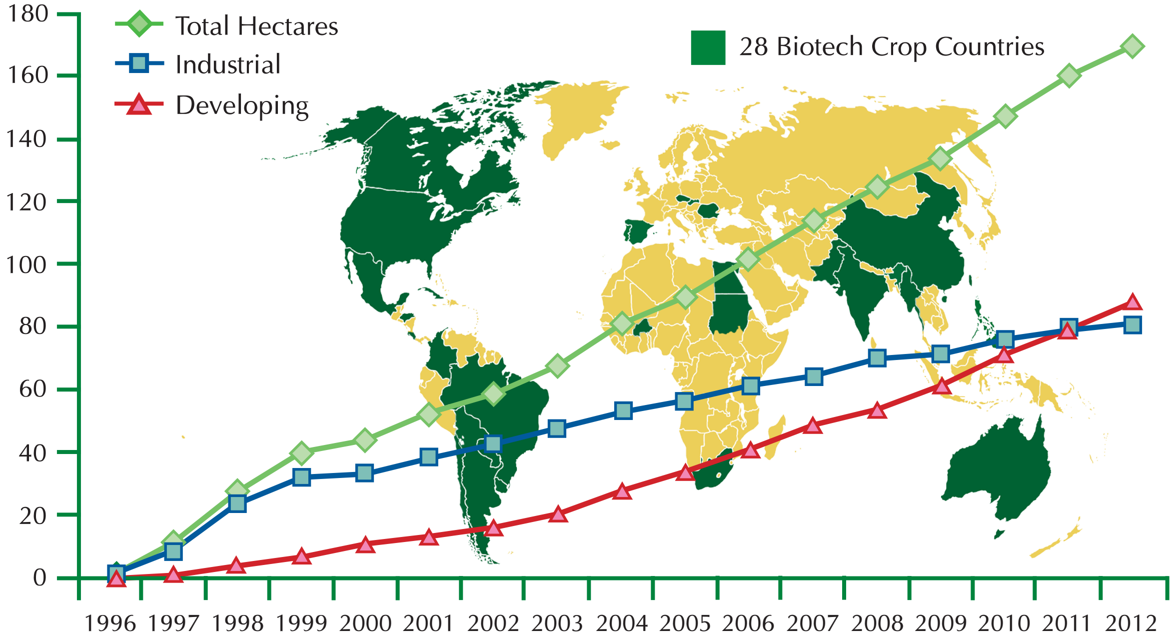
Global Status of Commercialized Biotech/GM Crops: 2012

By

Clive James
Chair, ISAAA Board of Directors

Dedicated by the author to the 1 billion poor and hungry people, and their survival

GLOBAL AREA OF BIOTECH CROPS
Million Hectares (1996-2012)



A record 17.3 million farmers, in 28 countries, planted 170.3 million hectares (420 million acres) in 2012, a sustained increase of 6% or 10.3 million hectares (25 million acres) over 2011.

Source: Clive James, 2012.

No. 44 - 2012

AUTHOR’S NOTE:

Global totals of millions of hectares planted with biotech crops have been rounded off to the nearest million and similarly, subtotals to the nearest 100,000 hectares, using both < and > characters; hence in some cases this leads to insignificant approximations, and there may be minor variances in some figures, totals, and percentage estimates that do not always add up exactly to 100% because of rounding off. It is also important to note that countries in the Southern Hemisphere plant their crops in the last quarter of the calendar year. The biotech crop areas reported in this publication are planted, not necessarily harvested hectarage in the year stated. Thus, for example, the 2012 information for Argentina, Brazil, Australia, South Africa, and Uruguay is hectares usually planted in the last quarter of 2012 and harvested in the first quarter of 2013 with some countries like the Philippines having more than one season per year. Thus, for countries of the Southern hemisphere, such as Brazil, Argentina and South Africa the estimates are projections, and thus are always subject to change due to weather, which may increase or decrease actual planted hectares before the end of the planting season when this Brief has to go to press. For Brazil, the winter maize crop (safrinha) planted in the last week of December 2012 and more intensively through January and February 2013 is classified as a 2012 crop in this Brief consistent with a policy which uses the first date of planting to determine the crop year. ISAAA is a not-for-profit organization, sponsored by public and private sector organizations. All biotech crops hectare estimates reported in all ISAAA publications are only counted once, irrespective of how many traits are incorporated in the crops. Details of the references listed in the Executive Summary are found in the full Brief 44.

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No. 44 - 2012

Published by: The International Service for the Acquisition of Agri-biotech Applications (ISAAA).

Citation: James, Clive. 2012. Global Status of Commercialized Biotech/GM Crops: 2012. *ISAAA Brief* No. 44. ISAAA: Ithaca, NY.

ISBN: 978-1-892456-53-2

Publication Orders and Price: Please contact the ISAAA *SEAsia*Center to purchase a hard copy of the full version of Brief 44, including the Executive Summary and the Highlights at http://www.isaaa.org. The publication is available free of charge to eligible nationals of developing countries.

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Highlights of "Global Status of Commercialized Biotech/GM Crops: 2012"

By Clive James, Founder and Chair of ISAAA

Dedicated by the author to the 1 billion poor and hungry people, and their survival

Biotech Crop hectares increased by an unprecedented 100-fold from 1.7 million hectares in 1996, to 170 million hectares in 2012

A record 170.3 million hectares of biotech crops were grown globally in 2012, at an annual growth rate of 6%, up 10.3 million from 160 million hectares in 2011.

2012 marked an unprecedented 100-fold increase in biotech crop hectarage from 1.7 million hectares in 1996 to 170 million hectares in 2012 – this makes biotech crops the fastest adopted crop technology in recent history – the reason – they deliver benefits.

In the period 1996 to 2012, millions of farmers in ~30 countries worldwide, made more than 100 million independent decisions to plant an accumulated hectarage of more than 1.5 billion hectares – 50% more than the land mass of the US or China; this demonstrates the trust and confidence of millions of risk-averse farmers in biotech crops which deliver sustainable and substantial, socioeconomic and environmental benefits.

Two new countries, Sudan (Bt cotton) and Cuba (Bt maize) planted for the first time in 2012. Germany and Sweden could not plant the potato "Amflora" because it ceased to be marketed; Poland discontinued planting Bt maize because of regulation constraints.

Of the 28 countries which planted biotech crops in 2012, 20 were developing and 8 were industrial countries; this compares with 19 developing and 10 industrial in 2011.

In 2012, a record 17.3 million farmers, up 0.6 million from 2011, grew biotech crops – remarkably over 90%, or over 15 million, were small resource-poor farmers in developing countries. Farmers are the masters of risk aversion and in 2012, a record 7.2 million small farmers in China and another 7.2 million in India, elected to plant almost 15 million hectares of Bt cotton, because of the significant benefits it offers.

For the first time, developing countries grew more, 52%, of global biotech crops in 2012 than industrial countries at 48%. In 2012, growth rate for biotech crops was at least three times as fast, and five times as large in developing countries, at 11% or 8.7 million hectares, versus 3% or 1.6 million hectares in industrial countries.

Stacked traits are an important feature – 13 countries planted biotech crops with two or more traits in 2012, and encouragingly, 10 of the 13 were developing countries – 43.7 million hectares, or more than a quarter, of the 170 million hectares were stacked in 2012.

Brazil, for the fourth consecutive year, was the engine of growth globally, increasing its hectarage of biotech crops more than any other country – an impressive record increase of 6.3 million hectares, up 21% from 2011, reaching 36.6 million hectares.

The US continued to be the lead country with 69.5 million hectares, with an average 90% adoption across all crops. Impact of US 2012 drought for maize was 21% loss in productivity and in soybean,12%. Canada had a record 8.4 million hectares of canola at a record 97.5% adoption.

India grew a record 10.8 million hectares of Bt cotton with an adoption rate of 93%, whilst 7.2 million small resource-poor farmers in China grew 4.0 million hectares of Bt cotton with an adoption rate of 80%, cultivating on average 0.5 hectare per farmer. India enhanced farm income from Bt cotton by US$12.6 billion in the period 2002 to 2011 and US$3.2 billion in 2011 alone.

Africa continued to make progress with South Africa increasing its biotech area by a record 0.6 million hectares to reach 2.9 million hectares; Sudan joined South Africa, Burkina Faso and Egypt, to bring the total number of African biotech countries to four.

Five EU countries planted a record 129,071 hectares of biotech Bt maize, up 13% from 2011. Spain led the EU with 116,307 hectares of Bt maize, up 20% from 2011.

From 1996 to 2011, biotech crops contributed to Food Security, Sustainability and Climate Change by: increasing crop production valued at US$98.2 billion; providing a better environment, by saving 473 million kg a.i. of pesticides; in 2011 alone reducing CO_2 emissions by 23.1 billion kg, equivalent to taking 10.2 million cars off the road; conserving biodiversity by saving 108.7 million hectares of land; and helped alleviate poverty by helping >15.0 million small farmers and their families totalling >50 million people, who are some of the poorest people in the world. Biotech crops are essential but are not a panacea and adherence to good farming practices such as rotations and resistance management, are a must for biotech crops as they are for conventional crops.

The lack of appropriate, science-based and cost/time-effective regulatory systems continue to be the major constraint to adoption. Responsible, rigorous but not onerous, regulation is needed for small and poor developing countries.

Global value of biotech seed alone was valued at ~US$15 billion in 2012.

Future Prospects - cautiously optimistic with more modest annual gains predicted because of the already high rate of adoption in all the principal crops in mature markets in both developing and industrial countries.

Global Status of Commercialized Biotech/GM Crops: 2012

By

Clive James
Chair, ISAAA Board of Directors

Introduction

This Brief focuses on the global biotech crop highlights in 2012, and is dedicated to the 1 billion poor and hungry people, and their survival.

2012 marks the 17th anniversary of the commercialization, 1996-2012, of biotech crops, also known as genetically modified (GM) or transgenic crops, now more often called “biotech crops” as referred to in this Brief. The experience of the first 16 years of commercialization, 1996 to 2011, confirmed that the early promise of crop biotechnology has been fulfilled. Biotech crops have delivered substantial agronomic, environmental, economic, health and social benefits to farmers and, increasingly, to society at large. The rapid adoption of biotech crops, during the initial 16 years of commercialization, 1996 to 2011, reflects the substantial multiple benefits realized by both large and small farmers in industrial and developing countries, which have grown biotech crops commercially. Between 1996 and 2011, developing and industrial countries contributed to a record 94-fold increase in the global area of biotech crops from 1.7 million hectares in 1996 to 160 million hectares in 2011. Adoption rates for biotech crops during the period 1996 to 2011 were unprecedented and, by recent agricultural industry standards, they represent the highest adoption rates for improved crops, for example, higher than the adoption of hybrid maize in its heyday in the mid-west of the USA. High adoption rates reflect farmer satisfaction with the products that offer substantial benefits ranging from more convenient and flexible crop management, lower cost of production, higher productivity and/or net returns per hectare, health and social benefits, and a cleaner environment through decreased use of conventional pesticides, which collectively contribute to a more sustainable agriculture. There is a growing body of consistent evidence across years, countries, crops and traits generated by public sector institutions that clearly demonstrate the benefits from biotech crops. These benefits include improved weed and insect pest control with biotech herbicide tolerant and insect resistant Bt crops, that also benefit from lower input and production costs; biotech crops also offer substantial economic advantages to farmers compared with corresponding conventional crops. The severity of weeds, insect pests and diseases varies from year-to-year and country to country, and hence location will directly impact pest control costs and the economic advantages of biotech crops in any given time or place.

Despite the continuing debate on biotech crops, particularly in countries of the European Union (EU), millions of large and small farmers in both industrial and developing countries have continued to increase their plantings of biotech crops by double-digit adoption growth rates almost every year since 1996, because of the significant multiple benefits that biotech crops offer. This high rate of adoption is a strong vote of confidence in biotech crops, reflecting farmer satisfaction in both industrial and developing countries. Around 17 million farmers in 29 countries grew biotech crops in 2011 and derived multiple benefits that included significant agronomic, environmental, health, social and economic advantages. ISAAA's 2011 Global Review (James, 2011) predicted that the global area of biotech crops, would continue to grow modestly in 2012. Global population was approximately 6.5 billion in 2006 and is expected to reach approximately up to 9.3 billion by 2050, when around 90% of the global population will reside in Asia, Africa, and Latin America. The latest projection by the UN Population (United Nations, 2011 World Population Prospects: The 2010 Revision) is that the population will continue to increase until the end of this century when it will plateau at 10.1 billion. In 2011, ~1 billion people in the developing countries suffered from hunger, malnutrition and poverty. Biotech crops represent promising technologies that can make a vital contribution, but are not a panacea, to global food, feed and fiber security. Biotech crops can also make a critically important contribution to the alleviation of poverty, the most formidable challenge facing global society which has made the commitment to the Millennium Development Goals (MDG) to cut poverty, hunger and malnutrition by half by 2015; this is also the year that marks the completion of the second decade of commercialization of biotech crops, 2006-2015.

The most compelling case for biotechnology, and more specifically biotech crops, is their capability to contribute to:

increasing crop productivity, and thus **contribute to global food, feed, and fiber security,** with benefits for producers, consumers and society at large alike; **contribute to more affordable food** as a result of coincidentally increasing productivity significantly and reducing production costs substantially;

self-sufficiency which is optimizing productivity and production on a nation's own arable land, whereas food security is "food for all" without specific reference to source – self-sufficiency and food security are not mutually exclusive, currently there is an increased emphasis on self-sufficiency by both national programs and donors;

conserving biodiversity – as a land-saving technology capable of higher productivity on the current ~1.5 billion hectares of arable land, biotech crops can help preclude deforestation and protect biodiversity in forests and in other in-situ biodiversity sanctuaries;

reducing the environmental footprint of agriculture by contributing to more efficient use of external inputs, thereby contributing to a safer environment and more sustainable agriculture systems; special attention should be assigned to more efficient use of water in crop production and development of drought tolerant biotech crops;

mitigating some of the challenges associated with climate change (increased frequency and severity of droughts, floods, epidemics, changes in temperature, rising sea levels exacerbating salinity and changes in temperature) and reducing greenhouse gases by using biotech applications for "speeding the breeding" in crop improvement programs to expedite the development of well adapted germplasm for rapidly changing climatic conditions and optimize the sequestration of CO_2;

increasing stability of productivity and production to lessen suffering during famines due to biotic and abiotic stresses, particularly drought, which is the major constraint to increased productivity on the ~1.5 billion hectares of arable land in the world; and

the improvement of economic, health and social benefits, food, feed, and fiber security, and the alleviation of abject poverty, hunger and malnutrition for the rural population dependent on agriculture in developing countries who represent 70% of the world's poor; thus, **provide significant and important multiple and mutual benefits to producers, consumers and global society.**

A 2011 comprehensive study at the UN University, Tokyo (Adenle, 2011) concluded that: ***"there is an urgent need for the advancement of agricultural technology (e.g. crop biotechnology or genetic modification (GM) technology), particularly, to address food security problem, to fight against hunger and poverty crisis and to ensure sustainable agricultural production in developing countries. Over the past decade, the adoption of GM technology on a commercial basis has increased steadily around the world with a significant impact in terms of socio-economic, environment and human health benefits. However, GM technology is still surrounded by controversial debates with several factors hindering the adoption of GM crops."*** The study reviewed current literature on commercial production of GM crops, and assessed the benefits and constraints associated with adoption of GM crops in developing countries in the last 15 years. The manuscript provides policy guidance to facilitate the development and adoption of GM technology in developing countries.

The most promising technological option for increasing global food, feed and fiber production is to combine the best of the old and the best of the new by integrating the best of conventional technology (adapted germplasm) and the best of biotechnology applications, including molecular breeding and the incorporation of transgenic novel traits. The improved crop products, resulting from the synergy of combining the best of the old with the best of the new must then be incorporated as the **innovative technology** component in a global food, feed and fiber security strategy that must also address other critical issues, including population control and improved food, feed and fiber distribution. Adoption of such a holistic strategy will allow society to continue to benefit from the vital contribution that both conventional and modern innovative plant breeding offers global society.

The author has published global reviews of biotech crops annually since 1996 as ISAAA Briefs: James, 2011; James, 2010; James, 2009; James, 2008; James, 2007; James, 2006; James, 2005; James, 2004; James, 2003; James, 2002; James, 2001; James, 2000; James, 1999; James, 1998; James, 1997; James and Krattiger, 1996). This publication provides the latest information on the global status of commercialized biotech crops. A detailed global data set on the adoption of commercialized biotech crops is presented for the year 2012 and the changes that have occurred between 2011 and 2012 are highlighted. The global adoption trends during the last 17 years from 1996 to 2012 are also illustrated as well as the contribution of biotech crops to the world's 1 billion poor people, of which resource-poor farmers are a significant proportion.

This ISAAA Annual Global Review of biotech crops (Brief 44, 2012) is the seventeenth in an annual series. It documents the global database on the adoption and distribution of biotech crops in 2012 and in the Appendix there are four sections: 1) a table with global status of crop protection in 2011, courtesy of Cropnosis; 2) useful tables and charts on the international seed trade – these have been reproduced with permission of the International Seed Federation (ISF); 3) a table detailing the deployment of Bt cotton hybrids and varieties in India in 2012; and 4) Listing of events, Bt cotton varieties and hybrids in India in 2012.

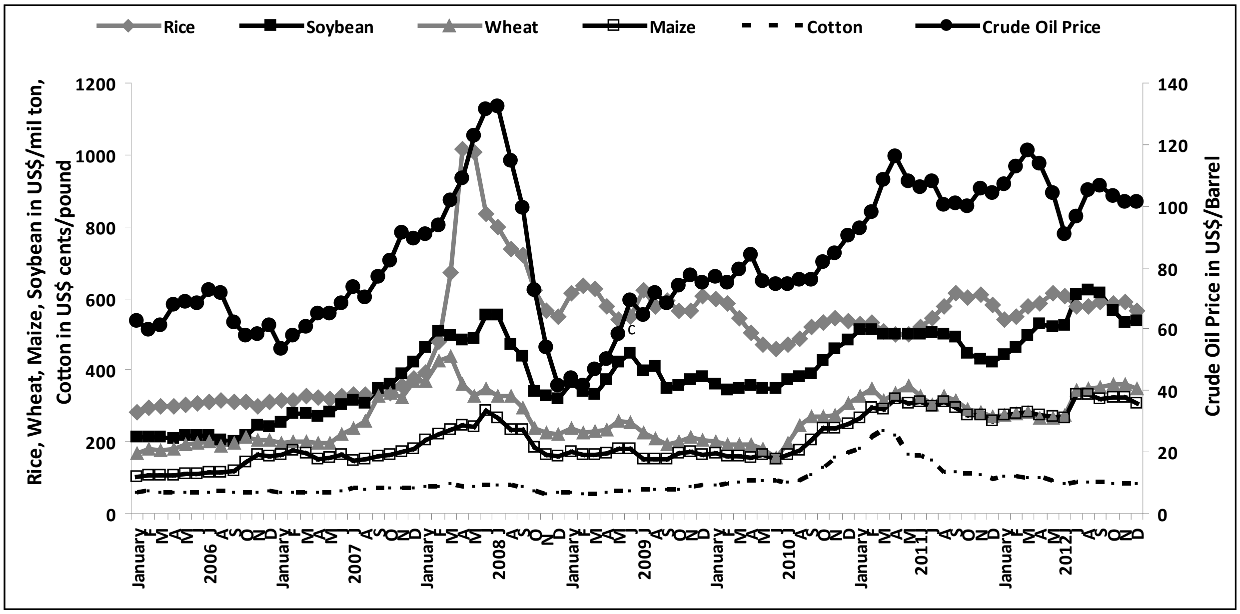
Note that the words rapeseed, canola, and Argentine canola are used synonymously, as well as transgenic, genetically modified crops, GM crops, and biotech crops, reflecting the usage of these words in different regions of the world, with biotech crops being used exclusively in this text because of its growing usage worldwide. Similarly, the words corn, used in North America, and maize, used more commonly elsewhere in the world, are synonymous, with maize being used consistently in this Brief, except for common names like corn rootworm where global usage dictates the use of the word corn. All $ dollar values in this Brief are US dollars unless otherwise noted. Some of the listed references may not be cited in the text – for convenience they have been included because they are considered useful reading material and were used as preparatory documents for this Brief. Global totals of millions of hectares planted with biotech crops have been rounded off to the nearest million and similarly subtotals to the nearest 100,000 hectares, using both < and > characters; hence in some cases this leads to insignificant approximations, and there may be minor variances in some figures, totals, and percentage estimates that do not always add up exactly to 100% because of rounding off. It is also important to note that countries in the Southern Hemisphere plant their crops in the last quarter of the calendar year. The biotech crop areas reported in this publication are planted, not necessarily harvested hectarage, in the year stated. Thus, for example, the 2012 information for Argentina, Brazil, Australia, South Africa, and Uruguay is hectares usually planted in the last quarter of 2012 and harvested in the first quarter of 2013, or later, with some countries like the Philippines planting crops in more than one season per year. Thus, for countries of the Southern hemisphere, such as Brazil and Argentina the estimates are projections, and thus are always subject to change due to weather, which may increase or decrease actual planted area before the end of the planting season when this Brief went to press. For Brazil, the winter maize crop (safrinha) planted at the end of December 2012 and more intensively through January and February 2013, is classified as a 2012 crop in this Brief, consistent with a policy which uses the first date of planting to determine the crop year. Country figures were sourced from The Economist, supplemented by data from World Bank, FAO and UNCTAD, when necessary.

Over the last 17 years, ISAAA has devoted considerable effort to consolidate all the available data on officially approved biotech crop adoption globally; it is important to note that the database does not include plantings of biotech crops that are not officially approved. The database draws on a large number of sources of approved biotech crops from both the public and private sectors in many countries throughout the world. The range of crops is those defined as food, feed and fiber crops in the FAO database. Data sources vary by country and include, where available, government statistics, independent surveys, and estimates from commodity groups, seed associations and other groups, plus a range of proprietary databases. Published ISAAA estimates are, wherever possible, based on more than one source of information and thus are usually not attributable to one specific source. Multiple sources of information for the same data point greatly facilitate assessment, verification, and validation of specific estimates. The "proprietary" ISAAA database on biotech crops is unique from two points of view; first, it provides a global perspective; second, it has used the same basic methodology, improved continuously for the last 17 years and hence provides continuity from the genesis of the commercialization of biotech crops in 1996, to the present. The database has gained acceptance internationally as a reliable benchmark of the global status of biotech food, feed and fiber crops and is widely cited in the scientific literature and the international press.

Global Area of Biotech Crops in 2012

Following the drought of 2012 in the USA, prices of maize and soybean climbed significantly and the IMF data in Figure 1 shows a generally upward trend paralleling the high prices of 2008. On the other hand, the price of cotton plummeted in 2011 and this led to about a 10% decrease in hectarage of cotton in 2012 which also resulted in a decrease in hectarage of biotech cotton globally in 2012. A significant increase in the price of food and feed products are predicted for 2013. The buoyant food, feed and fiber prices in 2012 have provided incentives for farmers worldwide, resulting in increased

Figure 1. International Prices of Crop Commodities and a Barrel of Crude Oil, 2006 to December 2012



Source: International Monetary Fund, 2012.

hectarages of the principal crops and more investments in improved technologies, including biotech crops.

Thus, in 2012, a record 170.3 million hectares of biotech crops were planted by 17.3 million farmers in 28 countries, compared with 160 million hectares grown by 16.7 million farmers in 29 countries in 2011 (Table 1). Of the total number of 28 countries planting biotech crops in 2012, 20 were developing countries and 8 industrial countries (Figure 4). It is notable that 10.3 million hectares more were planted in 2012 by 17.3 million farmers in the 17th year of commercialization at a growth rate of 6% equivalent. The highest increase in any country, in absolute hectarage growth, was Brazil with 6.3 million hectares followed by Canada at 1.2 million hectares, and Paraguay and South Africa at 0.6 million hectares (Table 3). It is notable that five EU countries grew a record hectarage of 129,071 hectares compared with 114,490 hectares in 2011, a significant 13% increase of biotech crops in 2012.

To put the 2012 global area of biotech crops into context, 170 million hectares of biotech crops is equivalent to approximately 18% of the total land area of China (956 million hectares) or the USA (937 million hectares) and more than 7 times the land area of the United Kingdom (24.4 million hectares). The increase in area between 2011 and 2012 of 6% is equivalent to 10.3 million hectares or 25 million acres (Table 1).

Table 1. Global Area of Biotech Crops, the First 17 Years, 1996 to 2012

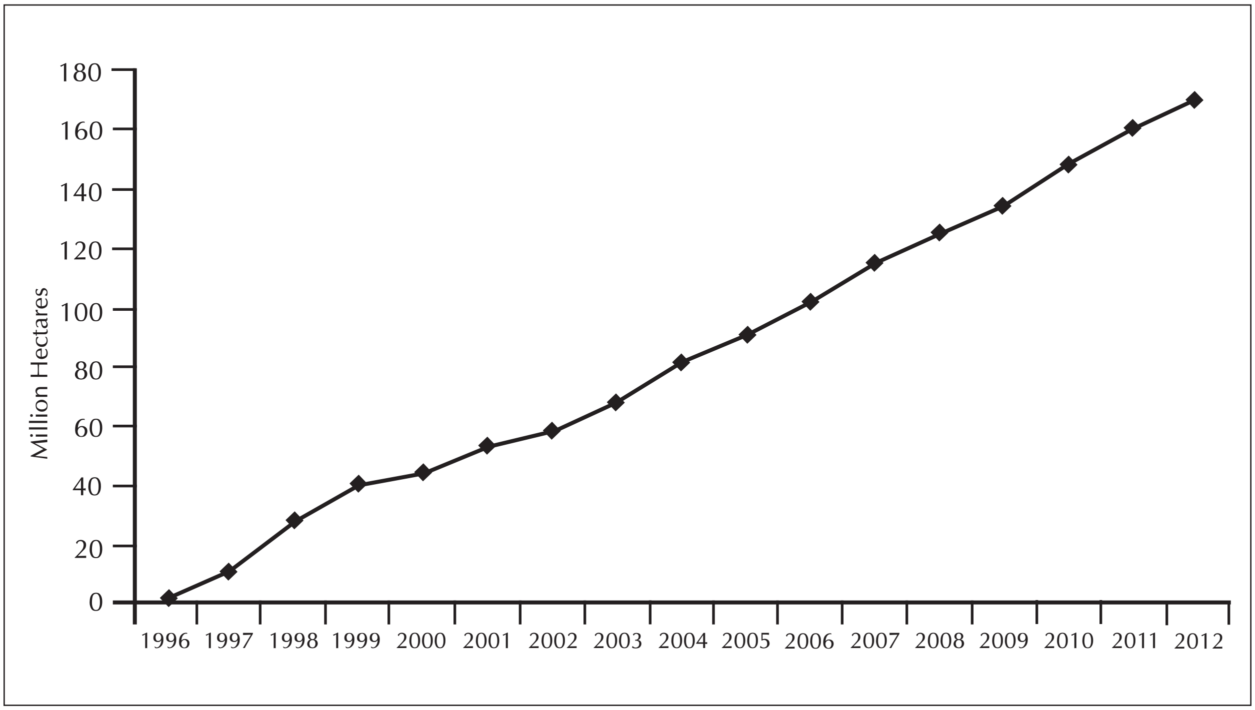
Year	Hectares (million)	Acres (million)
1996	1.7	4.3
1997	11.0	27.5
1998	27.8	69.5
1999	39.9	98.6
2000	44.2	109.2
2001	52.6	130.0
2002	58.7	145.0
2003	67.7	167.2
2004	81.0	200.0
2005	90.0	222.0
2006	102.0	252.0
2007	114.3	282.0
2008	125.0	308.8
2009	134.0	335.0
2010	148.0	365.0
2011	160.0	395.0
2012	170.3	420.8
Total	**1,427.3**	**3,531.8**

Increase of 6%, 10.3 million hectares (25 million acres) between 2011 and 2012.
Source: Clive James, 2012.

During the seventeen years of commercialization 1996 to 2012, the global area of biotech crops increased 100-fold, from 1.7 million hectares in 1996 to 170.3 million hectares in 2012 (Figure 2). This rate of adoption is the highest rate of crop technology adoption for any crop technology and reflects the continuing and growing acceptance of biotech crops by farmers in both large as well as small and resource-poor farmers in industrial and developing countries. In the same period, the number of countries growing biotech crops more than quadrupled, increasing from 6 in 1996 to 12 countries in 1999, 17 in 2004, 21 countries in 2005, 25 in 2009, 29 in 2010 and 2011 but decreased to 28 in 2012. A new wave of adoption of biotech crops is fueled by several factors which are contributing to a broad-based global growth in biotech crops. These factors include: 28 countries (developing and industrial) already planting biotech crops in 2012, with a strong indication that several new countries will join in the near term; notable and significant continuing progress in Africa with four African countries (South Africa, Burkina Faso, Egypt and Sudan, collectively planting over 3.32 million hectares in 2012. Africa is the continent with the greatest challenge; significant increases in hectarage of "new" biotech crops such as biotech maize in Brazil opens up significant additional potential hectarage for biotech crops; newly approved biotech crop products, such as the IR/HT soybean approved for Brazil and the US; resumption of RR®alfalfa planting in the US – alfalfa is the fourth largest crop in the US (8 million hectares) after maize, soybean and wheat; approval of the virus resistant bean in Brazil; continuing growth in stacked traits in cotton and maize, increasingly deployed by 13 countries worldwide; and a new second generation events with quality traits such as Golden Rice enriched with vitamin A, and soybean with healthier omega-3 oil.

This new wave of adoption is providing a seamless interface with the first wave of adoption, resulting in continued and broad-based strong and stable growth in global hectarage of biotech crops. In 2012, the accumulated hectarage (planted since 1996) surged to 1.43 billion hectares or 3.5 billion acres. In 2012, developing countries continued to out-number industrial countries by 6.7 million hectares and for the first time, developing countries grew more than 50% of the global biotech crop hectarage. This trend of higher adoption by developing countries is expected to continue in the future with up to 40 countries, expected to adopt biotech crops by 2015, the end of the second decade of commercialization. By coincidence, 2015 also happens to be the Millennium

Figure 2. Global Area of Biotech Crops, 1996 to 2012 (Million Hectares)



Source: Compiled by Clive James, 2012.

Development Goal year, when global society has pledged to cut poverty and hunger in half – a vital humanitarian goal that biotech crops can contribute to, in an appropriate and significant way in developing countries. The MDG provides global society and the scientific community with a one-time opportunity to urgently set explicit humanitarian goals, more specifically the imperative priority of food security and reducing hunger and poverty by 50% by 2015, to which biotech crops can make a significant contribution.

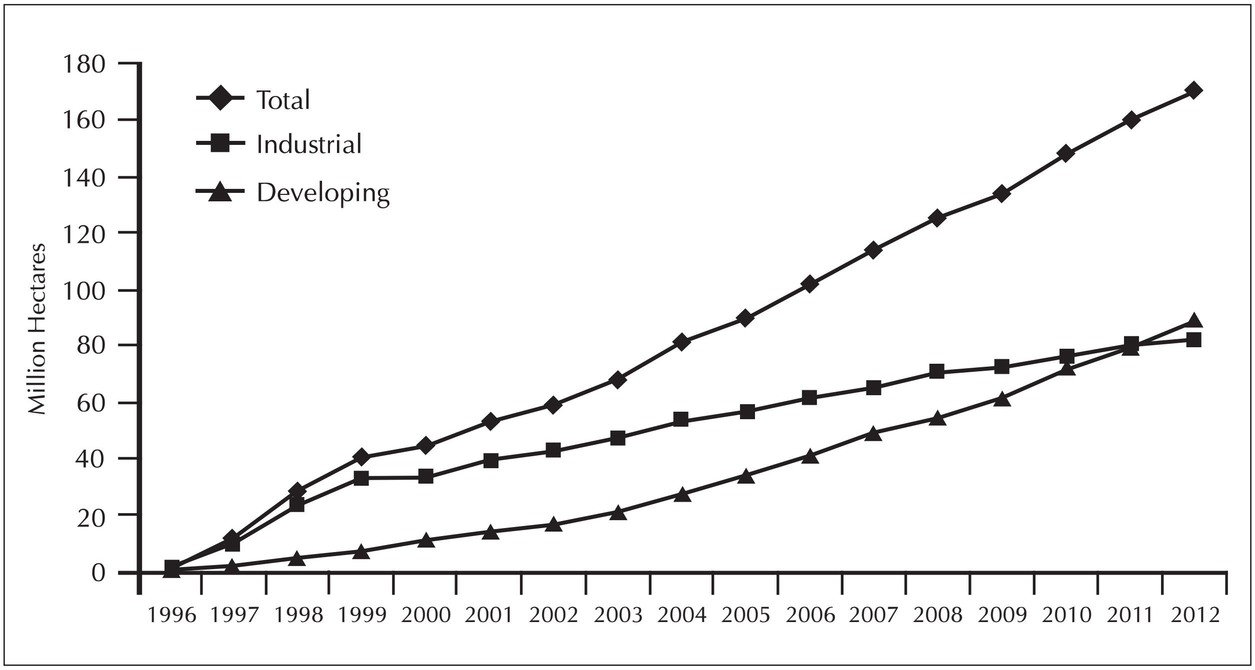
In summary, during the first seventeen years of commercialization 1996 to 2012, an accumulated total of 1.43 billion hectares, equivalent to 3.5 billion acres of biotech crops, have been successfully grown as a result of ~100 million independent decisions by farmers to plant biotech crops (Table 1). Farmers have signaled their strong vote of confidence in crop biotechnology by consistently increasing their plantings of biotech crops by high growth rates every single year since biotech crops were first commercialized in 1996, with the number of biotech countries more than quadrupling from 6 to 28 in the same 17-year period.

Distribution of Biotech Crops in Industrial and Developing Countries

Figure 3 shows the relative hectarage of biotech crops in industrial and developing countries during the period 1996 to 2012. It illustrates that in 2012 for the first time, developing countries planted more than half of 170.3 million hectares of global biotech crops. In 2012, developing countries planted 52% equivalent to 88.5 million hectares compared to 48% or 81.8 million hectares in industrial countries (Table 2). Figure 3 illustrates that prior to 2012, the proportion of biotech crops grown in developing countries had increased consistently every single year from 14% in 1997 to 16% in 1998, 18% in 1999, 24% in 2000, 26% in 2001, 27% in 2002, 30% in 2003, 34% in 2004, 38% in 2005, 40% in 2006, 43% in 2007, 44% in 2008, 46% in 2009, 48% in 2010, 50% in 2011 and 52% in 2012. Thus, in 2012, more than half of the global biotech crop area of 170.3 million hectares, equivalent to 88.5 million hectares, was grown in 20 developing countries where growth continued to be strong, compared with the 8 industrial countries growing 81.8 million hectares of biotech crops equivalent to 48% (Table 2). The increase in hectarage between 2011 and 2012 for developing countries was 8.7 million hectares or 11% versus 1.6 million hectares or 3% in industrial countries – thus, growth was more than three times as fast in developing countries compared with industrial countries, whether measured in absolute hectares or in percentage growth. The strong trend for higher growth in developing countries versus industrial countries is highly likely to continue in the near, mid and long-term, as more countries from the South adopt biotech crops and crops like rice, 90% of which is grown in developing countries, are deployed as new biotech crops.

Of the US$98.2 billion additional gain in farmer income generated by biotech crops in the first 16 years of commercialization (1996 to 2011), it is noteworthy that, US$48.6 billion was generated in

Figure 3. Global Area of Biotech Crops, 1996 to 2012: Industrial and Developing Countries (Million Hectares)



Source: Clive James, 2012.

Table 2. Global Area of Biotech Crops, 2011 and 2012: Industrial and Developing Countries (Million Hectares)

	2011	%	2012	%	+/-	%
Industrial countries	80.23	50	81.8	48	1.6	+3
Developing countries	79.8	50	88.5	52	8.7	+11
Total	**160.0**	**100**	**170.3**	**100**	**10.3**	**+6**

Source: Clive James, 2012.

industrial countries and US$49.6 billion in developing countries. Moreover, in 2011, developing countries had a slightly larger share, 51.2% equivalent to US$10.1 billion of the total US$19.7 billion gain, with industrial countries at 48.8% or US$9.6 billion (Brookes and Barfoot, 2013, Forthcoming). The slightly larger share for developing countries in 2011 reflects the higher growth rates in developing countries in more recent years, which is expected to continue in the future.

Distribution of Biotech Crops, by Country

A total of 28 countries, 20 developing and 8 industrial countries, planted biotech crops in 2012 – this compares with 29 countries, 19 developing and 10 industrial in 2011. Two new developing countries Sudan and Cuba joined in 2012, planting a combined total of 23,000 hectares. Bt cotton was planted for the first time in Sudan and Bt maize was planted in Cuba for the first time. Three industrial countries, Poland, Sweden and Germany, which planted a combined total of ~3,000 hectares in 2011, did not plant any in 2012. Farmers in Germany and Sweden, who favored and planted "Amflora" potato in 2011 could not purchase "seed" in 2012 because the technology developer, BASF did not offer it for sale in the EU in 2012. Poland could not obtain seed of Bt maize although the EU notified Poland that Bt maize was approved for the country, and did not require further approvals.

The top ten countries, each of which grew over 1 million hectares in 2012, are listed by hectarage in Table 3 and Figure 4, led by the USA which grew 69.5 million hectares (41% of global total), Brazil with 36.6 million hectares (21%), Argentina with 23.9 million hectares (14%), Canada with 11.6 million hectares (7%), India with 10.8 million hectares (6%), China with 4.0 million hectares (2%), Paraguay with 3.4 million hectares (2%), South Africa 2.9 million hectares (2%), Pakistan 2.8 million hectares (2%), and Uruguay with 1.4 million hectares or 1% of global biotech hectarage. An additional 18 countries grew a total of approximately 4.0 million hectares in 2012 (Table 3 and Figure 4). It should be noted that of the top ten countries, each growing 1.0 million hectares or more of biotech crops, the majority (8 out of 10) are developing countries, Brazil, Argentina, India, China, Paraguay, South Africa, Pakistan, and Uruguay compared with only two industrial countries, USA and Canada. The number of biotech mega-countries (countries which grew 50,000 hectares, or more, of biotech crops) was 18, compared to 17 in 2011. Two of the three African countries (South Africa and Burkina Faso) are already mega-countries, with Burkina Faso qualifying in only the second year of commercialization. Notably, 14 of the 18 mega-countries are developing countries from Latin America, Asia and Africa. The high proportion of biotech mega-countries in 2012, 18 out of 28, equivalent to 60% reflects the significant broadening, deepening and stabilizing in biotech crop adoption that has occurred within the group of more progressive mega-countries adopting more than 50,000 hectares of biotech crops, on all six continents in the last 17 years.

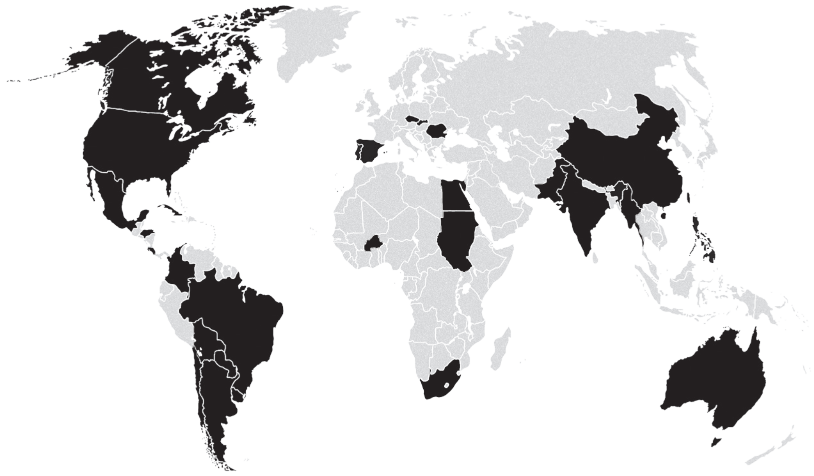
Table 3. Global Area of Biotech Crops in 2011 and 2012: by Country (Million Hectares)**

	Country	2011	%	2012	%	+/-	%
1	USA*	69.0	43	69.5	41	+0.5	+ 1
2	Brazil*	30.3	19	36.6	21	+6.3	+ 21
3	Argentina*	23.7	15	23.9	14	+0.2	+ 1
4	Canada*	10.4	7	11.6	7	+1.2	+ 12
5	India*	10.6	7	10.8	6	+0.2	+ 2
6	China*	3.9	2	4.0	2	+0.1	+ 3
7	Paraguay*	2.8	2	3.4	2	+0.6	+ 21
8	South Africa*	2.3	1	2.9	2	+0.6	+ 26
9	Pakistan*	2.6	2	2.8	2	+0.2	+ 8
10	Uruguay*	1.3	1	1.4	1	+0.1	+ 8
11	Bolivia*	0.9	1	1.0	1	+0.1	+ 11
12	Philippines*	0.6	<1	0.8	<1	+0.2	– –
13	Australia*	0.7	<1	0.7	<1	<0.1	– –
14	Burkina Faso*	0.3	<1	0.3	<1	<0.1	– –
15	Myanmar*	0.3	<1	0.3	<1	– –	– –
16	Mexico*	0.2	<1	0.2	<1	– –	– –
17	Spain*	0.1	<1	0.1	<1	– –	– –
18	Chile*	<0.1	<1	<0.1	<1	<0.1	– –
19	Colombia	<0.1	<1	<0.1	<1	<0.1	– –
20	Honduras	<0.1	<1	<0.1	<1	<0.1	– –
21	Sudan	<0.1	<1	<0.1	<1	<0.1	– –
22	Portugal	<0.1	<1	<0.1	<1	<0.1	– –
23	Czech Republic	<0.1	<1	<0.1	<1	<0.1	– –
24	Cuba	<0.1	<1	<0.1	<1	<0.1	– –
25	Egypt	<0.1	<1	<0.1	<1	<0.1	– –
26	Costa Rica	<0.1	<1	<0.1	<1	<0.1	– –
27	Romania	<0.1	<1	<0.1	<1	<0.1	– –
28	Slovakia	<0.1	<1	<0.1	<1	<0.1	– –
	Total	**160.0**	**100**	**170.3**	**100**	**+10.3**	**+6**

***Biotech mega-countries growing 50,000 hectares, or more.**
****Rounded-off to the nearest hundred thousand.**

Source: Clive James, 2012.

Figure 4. Global Area (Million Hectares) of Biotech Crops, 1996 to 2012, by Country, and Mega-Countries, and for the Top Ten Countries



Biotech Mega-Countries

50,000 hectares, or more

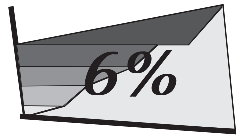
1.	USA	69.5 million
2.	*Brazil**	36.6 million
3.	*Argentina**	23.9 million
4.	Canada	11.6 million
5.	*India**	10.8 million
6.	*China**	4.0 million
7.	*Paraguay**	3.4 million
8.	*South Africa**	2.9 million
9.	*Pakistan**	2.8 million
10.	*Uruguay**	1.4 million
11.	*Bolivia**	1.0 million
12.	*Philippines**	0.8 million
13.	Australia	0.7 million
14.	*Burkina Faso**	0.3 million
15.	*Myanmar**	0.3 million
16.	*Mexico**	0.2 million
17.	Spain	0.1 million
18.	*Chile**	0.1 million

Less than 50,000 hectares

*Colombia**
*Honduras**
*Sudan**
Portugal
Czech Republic
*Cuba**
*Egypt**
*Costa Rica**
Romania
Slovakia

** Developing countries*

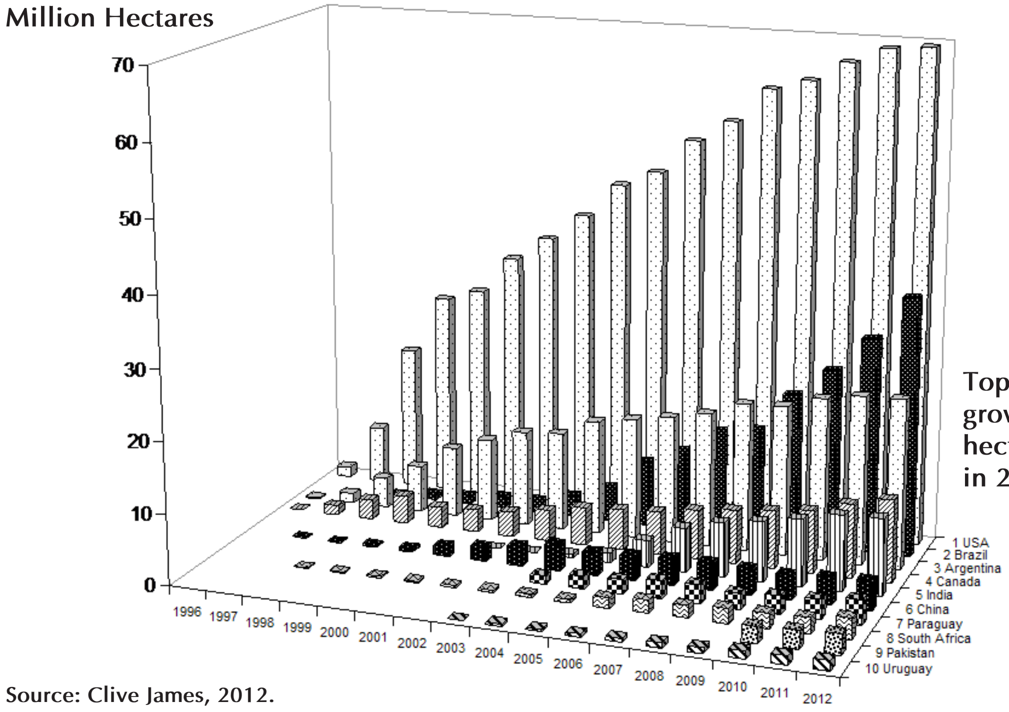
Increase over 2011



■ 28 countries which have adopted biotech crops

In 2012, global area of biotech crops was 170.3 million hectares, representing an increase of 6% over 2011, equivalent to 10.3 million hectares.

Source: Clive James, 2012.



Top 10 countries growing 1 million hectares, or more in 2012

Source: Clive James, 2012.

It is noteworthy, that in absolute hectares, the largest year-over-year growth, by far, was Brazil at 6.3 million hectares, followed by Canada at 1.2 million hectares, Paraguay and South Africa at 0.6 million hectares each. The top three in terms of global share of the 170 million hectares planted globally were USA at 41%, Brazil at 21% and Argentina at 14%.

Sudan, planting Bt cotton joins the group of 20 developing countries planting biotech crops in 2012

In the first twelve years of commercialization of biotech crops, 1996 to 2007, South Africa was the only country on the continent of Africa to commercialize biotech crops, and Africa is recognized as the continent that represents by far the biggest challenge in terms of adoption and acceptance. Accordingly, the decision in 2008 of Burkina Faso to grow Bt cotton and for Egypt to commercialize Bt maize for the first time was of strategic importance for the African continent. For the first time in 2008, there was a lead country commercializing biotech crops in each of the three major regions of the continent – South Africa in Southern and Eastern Africa, Burkina Faso in West Africa and Egypt in North Africa. In a landmark development, this year, 2012, the Republic of Sudan became the fourth African country to commercialize biotech cotton. Sudan planted approximately 20,000 hectares of Bt cotton in 2012 in both rainfed and irrigated areas. Sudan's intent is to rapidly extend the hectarage in the near term, well beyond the initial 20,000 hectares. Sudan is an important producer of cotton and has approximately 150,000 hectares of cotton under cultivation – in the past the hectarage was much higher and biotech cotton could help restore higher hectarage of cotton in the country. There are plans to call for early deployment of biotech cotton with stacked genes that confer resistance to pests and tolerance to herbicides, thus generating multiple benefits. This broader geographical coverage of biotech crops in Africa is of strategic importance because it allows more Africans to become practitioners of biotech crops and be able to benefit directly from "learning by doing", which has proven to be very important in China and India. Hectarage of biotech crops in all four African countries in 2012 totaled more than 2.9 million hectares most of which was grown in South Africa, which has cultivated biotech crops and benefited from them for more than ten years – the benefits to South Africa in 2011 alone was U$98 million.

Cuba joins the group of 20 developing countries planting biotech crops in 2012

The other new country that commercialized the planting of biotech crops in 2012 was Cuba in central America. For the first time, farmers in Cuba grew 3,000 hectares of hybrid Bt maize in a "regulated commercialization" initiative in which farmers seek permission to grow biotech maize commercially. The initiative is part of an ecological sustainable pesticide-free program featuring biotech maize hybrids and mycorrhizal additives. The Bt maize, with resistance to the major pest, fall armyworm, was developed by the Havana-based Institute for Genetic Engineering and Biotechnology (CIGB).

It is noteworthy, that there are now 11 countries in Latin America which benefit from the extensive adoption of biotech crops. Listed in descending order of hectarage, they are Brazil, Argentina, Paraguay, Uruguay, Bolivia, Mexico, Colombia, Chile, Honduras, Cuba and Costa Rica. It is also noteworthy, that Japan grew, for the fourth year, a commercial biotech flower, the "blue rose" in 2012. The rose was grown under partially covered conditions and not in "open field" conditions like the other food, feed and fiber biotech crops grown in other countries listed in this Brief. Australia and Colombia also grew biotech carnations.

Status of Bt maize in the EU

In 2012, five EU countries, Spain, Portugal, Czech Republic, Romania and Slovakia, grew MON 810 Bt maize. The "Amflora" potato cultivated by both Germany and Sweden in 2011, and favored by farmers, was not available for farmers to cultivate in 2012 because BASF ceased commercial operations for biotech crops in the EU in 2012. Despite halting commercialization of biotech crops specifically developed for the EU market in 2012, BASF confirmed that it would conduct field trials on up to 1 hectare in 2012 in Germany, Sweden and the Netherlands. Peter Eckes the President of BASF Plant Science stated that the trials are being conducted in order to ***"maintain all options for our potato varieties we will continue, as announced the approval processes underway and the multiplication of seed material for that purpose"*** (Reuters Hamburg, 5 April, 2012). Two types of biotech potatoes were trialed. The first was Fortuna, a biotech potato resistant to the devastating fungal disease, late blight, which caused the Irish famine of 1845 in which 1 million people perished. The second was Modena, a biotech potato with modified starch.

Poland was acknowledged to have planted Bt maize MON 810 in 2012 but hectarage estimates was not available because the biotech hybrids had not been registered in Poland although the EU court declared the Polish "ban" illegal. This is another example of unduly complex and contradictory EU regulation at the national and EU level resulting in confusion which understandably deters farmers from using or reporting the planting of biotech crops in many EU countries. Thus, Poland, in concert with France and Germany banned Bt maize in 2012, despite the fact that EFSA has endorsed Bt maize (MON 810) for cultivation in Europe. Spain grew ~90% of all the Bt maize in the EU. The hectarage of Bt maize in the EU in 2012 was a record 129,071 hectares, an increase of 13% over 2011 of which Spain grew a record 116,307 hectares.

Economic benefits of biotech crops

The six principal countries that have gained the most economically (over US$1 billion) from biotech crops, during the first 16 years of commercialization of biotech crops, 1996 to 2011 are, in descending order of magnitude, the USA (US$43.6 billion), Argentina (US$14 billion), China (US$13 billion), India (US$12.6 billion), Brazil (US$6.6 billion), Canada (US$4 billion), and others (US$4.4 billion) for a total of US$98.2 billion.

In 2011 alone, economic benefits globally were US$19.7 billion of which US$10.1 billion was for developing and US$9.6 billion was for industrial countries. The six countries that gained the most economically from biotech crops in 2011 were, in descending order of magnitude, the USA (US$8.8 billion), India (US$3.2 billion), China (US$2.2 billion), Argentina (US$1.9 billion), Brazil (US$2 billion), and Canada (US$0.6 billion), and others (US$1 billion) for a total of US$19.7 billion (Brookes and Barfoot, 2013, Forthcoming).

Country Chapters

USA

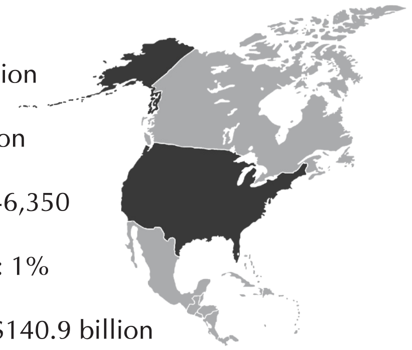
> **USA suffered its worst drought in fifty years in 2012. A chapter in this Brief provides an overview of the 2012 drought in the US, a summary of the occurrence of droughts globally in the last decade, and a review of progress in developing biotech drought tolerant maize which will be commercialized for the first time in the USA in 2013. In 2012, the USA continued to be the largest producer of biotech crops in the world with a global market share of 41%. In 2012, the USA planted a record hectarage of 69.5 million hectares of eight biotech crops (maize, soybean, cotton, canola, sugarbeet, alfalfa, papaya and squash), up from the 69.0 million hectares in 2011. The USA also leads in the deployment of stacked traits in maize (63% of total maize plantings) and cotton (63%) which offer farmers multiple and significant benefits. In 2012, the USA benefited from a sixth season of commercializing biotech RR®sugarbeet, which again occupied 487,000 hectares equivalent to a 97% adoption, in its sixth year of commercialization. This makes RR®sugarbeet the fastest ever adopted biotech crop globally. The adoption rates for the principal biotech crops in the USA: soybean, maize and cotton are close to optimal at an average of ~90%. Further significant increases will be achieved through: increase in crop plantings; stacking of multiple traits in the same crop; or the introduction of new biotech crops and/or traits. RR®alfalfa, first cleared for commercialization in 2005, and resumed in February 2011, has spurred strong farmer demand. It is estimated that the USA has enhanced farm income from biotech crops by US$43.6 billion in the first sixteen years of commercialization of biotech crops 1996 to 2011. This represents 44% of global benefits for the same period, and the benefits for 2011 alone are estimated at US$8.8 billion (representing 45% of global benefits in 2011). These are the largest gains for any biotech crop country. It is noteworthy, that on 6 November 2012, in California, USA, voters defeated Proposition 37, the proposed state petition on "Mandatory Labeling of Genetically Engineered Food Initiative" with the final result as No 53.7% and Yes 46.3%.**

The USA is the leader of the six "founder biotech crop countries", having spear-headed the commercialization of biotech crops in 1996, the first year of global commercialization of biotech crops. The USA continued to be the lead biotech country in 2012 with close to 70 million hectares of biotech crops. USDA estimates (USDA NASS, 2012) indicate that the percentage adoption of the three principal biotech crops were at, or close to, optimal adoption – biotech maize at 88% adoption was the same as 2011, soybean was 93% compared with 94% in 2011, whereas upland cotton at 94% was up from 90% in 2011, although upland cotton plantings decreased by 14% to 5.0 million hectares, down from 5.8 million hectares in 2011. The total hectarage planted to biotech maize, soybean, cotton, canola, sugarbeets, alfalfa, papaya and squash was 69.5 million hectares compared with 69.0 million hectares in 2011. Thus in the US, the three principal major biotech crops of soybean, maize and cotton are now at or close to optimal levels with an average of ~90%; biotech sugarbeets at 97% adoption and canola at 93%.

USA suffered its worst drought in fifty years in 2012. A chapter in this Brief provides an overview of the 2012 drought in the US, a summary of the occurrence of droughts globally in the last decade, and a review of progress in developing biotech drought tolerant maize, which will be commercialized for the first time in the USA in 2013.

In December 21, 2011, the US Department of Agriculture deregulated Monsanto's first generation drought tolerant trait for maize MON87460 which signalled the start of the on farm trials with 250 growers on 10,000 acres (4,000 hectares) across the western Great Plains in 2012, where there is extreme to exceptional drought. The trait developed by Monsanto in collaboration with BASF Plant Science is the first drought tolerant maize (Crop Biotech Update, 6 January 2012). DuPont Pioneer's conventional AQUAmax, which was developed through advanced breeding techniques was launched in 2011, and reported to have increased yields by 7% in stressed environments compared to corresponding conventional hybrids (Crop Biotech Update, 3 August 2012). Early field trial results of Monsanto's Genuity® DroughtGard™ Hybrids conducted in the Western Great Plains, in Central Texas and Eastern Kansas, released on 11 September reported up to a 6 bushel advantage over competitor hybrids. The biotech drought tolerant maize was developed

USA



Population: 308.8 million

GDP: US$14,093 billion

GDP per Capita: US$46,350

Agriculture as % GDP: 1%

Agricultural GDP: US$140.9 billion

% employed in agriculture: 2%

Arable Land (AL): 178 million hectares

Ratio of AL/Population*: 2.4

Major crops:
- Maize
- Sugarcane
- Wheat
- Soybean
- Sugarbeet
- Canola
- Cotton
- Alfalfa

Commercialized Biotech Crops:
- HT/Bt/HT-Bt Maize
- Bt/HT/Bt-HT Cotton
- Bt/HT Potato
- HT Soybean
- VR Squash
- Sugarbeet
- HT Canola
- VR Papaya
- HT Alfalfa

Total area under biotech crops and (%) increase in 2012:
69.5 Million Hectares (+1%)

Farm income gain from biotech, 1996-2011: $43.6 billion

*Ratio: % global arable land / % global population

Source: The Economist, supplemented with Data from the World Bank, FAO and UNCTAD when necessary.

as a package through selection of germplasm combined with a drought tolerant biotechnology trait and agronomic recommendations. Aside from the ability to survive in drought, the biotech maize plant also exhibits improved hydro-efficiency to ensure conservation of soil moisture and reduces yield loss from drought conditions (Crop Biotech Update, 12 September, 2012).

Total plantings of maize in the USA in 2012 were 39.0 million hectares, up ~5% from 2011 (NASS USDA Crop, 2012) and was the second largest hectarage of maize since 1937 when a record 39.4 million hectares of maize were planted. **The US hybrid maize seed market is valued at US$12 billion annually** and biotech maize continued to be attractive in the USA in 2012 because of increasing global demand for feed, ethanol and strong export sales. The US exports more than 40% of world exports of maize. Total plantings of soybean in the US in 2012 at 30.8 million hectares was up ~1% from 30.5 million hectares in 2011.

USDA estimated that drought conditions in the cotton-growing regions of the United States in 2012 reduced the country's total cotton production by more than 3% this season. Total plantings of upland cotton at 5.0 million hectares in 2012, was down by 14%, compared to 5.8 million hectares in 2011. In 2011, cotton reached historically high prices but prices were low in 2012 when hectarage on a global basis dropped by 10 to 15%. Canola hectarage in the USA was 661,000 hectares, up significantly from the 433,000 hectares in 2011. Total hectarage of sugarbeet in 2012 was similar at ~500,000 hectares in 2011. Estimates of alfalfa seedings for 2012, will not be available from USDA until the first quarter of 2013. However, they are not likely to be very different from 2011 seedings at approximately 1.3 million hectares – this includes alfalfa harvested as hay and alfalfa haylage and green chop. Alfalfa is planted as a forage crop and grazed or harvested and fed to animals, and seeded in the spring and the fall. Alfalfa is the fourth largest crop in the US at about 8 million hectares.

In 2012, the USA continued to grow more biotech crops (69.5 million hectares) than any other country in the world, equivalent to 41% of global biotech crop hectarage. Considering the already high level of adoption of biotech crops in the US at approximately 90%, the gain of 0.5 million hectares in 2012 was significant. This is consistent with steady increases in the percentage adoption for the major crops which are now close to optimal with biotech soybean at 93%, cotton at 94% adoption, maize at 88% adoption, canola at 93% and sugarbeet at 97%.

Adoption of biotech maize continued to climb with growth in the stacked traits. The two-trait stacked products include biotech maize and cotton crops with two different insect resistant genes (for European corn borer and corn root worm control in maize) or two stacked traits for insect resistance and herbicide tolerance in the same variety in both maize and cotton. The maize stacked products with three traits feature two traits for insect control (one for above-ground pests, and the other for below-ground pests) and one for herbicide tolerance. In addition to the USA, the other twelve countries which deployed stacked traits in 2012 were in descending order of hectarage: Brazil, Argentina, Canada, South Africa, Australia, the Philippines, Mexico, Uruguay, Chile, Honduras, Paraguay, and Colombia.

Sugarbeet growers have always faced significant challenges in weed management. In 2006, a small hectarage of a ‘new' and important biotech crop was planted for the first time in the USA. Roundup Ready (RR®) herbicide tolerant sugarbeet was first planted in 2006 to evaluate the new technology and to sell the sugar, pulp and molasses in the market place. In 2007, another small hectarage was planted, but because of very limited biotech seed availability, only one sugarbeet company was able to transition to Roundup Ready (RR®). With greater amounts of seed production, it was estimated that in 2008, 59% of the 437,246 hectares of sugarbeet planted in the USA, equivalent to 257,975 hectares were RR®sugarbeet. Farmers welcomed the commercialization of sugarbeet and were very pleased with the biotech product, which provided superior weed control, and was more cost-effective and easier to cultivate than conventional sugarbeet. Farmers cited many advantages of RR®sugarbeet over conventional including: the number of required cultivations cut by half, with 30% savings in fuel; significant labor savings including elimination of supplementary hand weeding and labor time; less soil compaction; provides an incentive and facilitates adoption of minimum or no till; number of herbicide applications decreased as well as the convenience of reliance on fewer types of herbicides; less crop damage from herbicide applications; and generally more profitable and convenient to cultivate than conventional sugarbeet. In 2008, growers became convinced of the value of RR®sugarbeet and were keen to support the development of other traits, which they know to be important including disease, insect and nematode resistance, and drought and cold tolerance.

Herbicide tolerant RR®sugarbeet were quickly and widely adopted by growers in the USA and Canada in 2009. For the first time in 2009, adequate supplies of many seed varieties were finally available for farmers. An estimated 95% or ~485,000 hectares of sugarbeet planted in the USA in 2009 were devoted to varieties improved through biotechnology. In the US in 2010, 2011 and 2012, the hectarage of sugarbeet was the same at approximately 485,000 hectares, of which 95% in 2011 and 97% in 2012 were biotech. Canadian growers planted approximately 15,000 hectares of biotech varieties in 2009, representing nearly 96% of the nation's sugarbeet crop, and in 2012, the adoption of biotech was at about the same level, 15,000, and close to 100% adoption. 2012 was the fourth year of commercial planting in Eastern Canada and the fourth year of commercial production in Western Canada. This very high adoption rate in the US of 97% in four years makes RR®sugarbeet the fastest ever adopted biotech crop since biotech crops were first commercialized in 1996, seventeen years ago. Given the unqualified success of RR®sugarbeet, the estimated hectares of RR®sugarbeet in the US and Canada in 2012 was approximately the same for 2011 and 2012 at up to 97% adoption for RR®sugarbeet equivalent to approximately 475,000 hectares in the US and similarly, Canada had a ~95% adoption equivalent to 15,000 hectares. During the last couple of years, critics have tried to pursue legal avenues for stopping or restricting planting of RR®sugarbeet, but the scientific and farming logic of biotech sugarbeet has resisted all the attempts in the courts by the critics. In a landmark decision RR®sugarbeet was deregulated by the USDA in July 2012 (USDA, 19 July 2012).

Adoption of RR®sugarbeet by processors, and the consumers understanding and acceptance (including the EU) that the "sugar is the same" pure and natural sweetener, has important implications regarding future acceptance of biotech sugarcane on a global basis. Globally, sugarcane occupies almost 25 million hectares and nine of the top 10 sugarcane countries are developing, led by Brazil (9 million hectares), India (4 million) and China (2 million). Developing countries grow sugarcane for food and ethanol production and biotech cane is likely to be available in the near term.

The very high level of satisfaction and demand by US and Canadian farmers for RR®sugarbeet probably has implications for sugarcane (80% of global sugar production is from cane) for which biotech traits are under development in several countries and approval for field trials was granted in Australia in October 2009. Sugarcane crops, improved through biotechnology, have not yet been commercialized. However, significant research is actively under way in Australia, Brazil, Colombia, Mauritius and South Africa, as well as the United States. Traits under study in cane include, sugar content and quality, herbicide tolerance, pest resistance, disease resistance, and drought, cold and salt tolerance.

Luther Markwart, executive vice president of the American Sugarbeet Association, said ***"Biotech sugarbeet seeds arrived just in time to save a struggling industry that is essential to our nation's food security. Sugar from sugarbeet currently provides about half of the nation's sugar consumption. Our industry leaders have spent over 10 years to develop, approve, adopt and transition our U.S. production to this important technology. Growers simply said if our industry is going to survive, we've got to have these kinds of tools. Roundup Ready beet seeds are saving producers money and making the crop much easier to manage. Weeds are our biggest problem. Typically, with conventional beets you have to use four to five applications of a combination of various herbicides. Now, farmers are using fewer chemicals and less fuel, and Roundup Ready doesn't stress the beets"*** (Murphy, 2008; Porter, 2009).

Herbicide tolerant RR®alfalfa was first approved for commercialization in the USA in June 2005. The first pre-commercial plantings (20,000 hectares) were sown in the fall of 2005, followed by larger plantings in 2006/2007 that brought the total to approximately 100,000 hectares. A court order (not based on safety reasons) filed by critics, stopped planting in 2007, pending completion of an environmental impact statement (EIS) by USDA. Farmers who had planted the 100,000 hectares of RR®alfalfa were not required to uproot the RR®alfalfa already planted which has remained in the ground for up to 6 years, due to the perennial nature of alfalfa which is normally ploughed at up to six years. On 21 June 2010, the Supreme Court overturned the ban, and on 16 December, USDA announced that the EIS was completed, and on 27 January it declared that planting of RR®alfalfa could be resumed on 2 February 2011 – the first planting since 2007. Farmer demand has been strong and it is estimated that up to 225,000 hectares of RR®alfalfa were seeded in 2012 bringing the total hectarage of this perennial crop planted in both 2011 and 2012 up to ~425,000 hectares. Approximately one-third (113 out of 381) of alfalfa farmers surveyed in 2011 reported seeding RR®alfalfa, and a remarkable 90% were pleased with the product. Up to 20%, or 1.5 million hectares of the total 8 million hectares of RR®alfalfa is reseeded every year. Some observers (The Daily Beast, 15 October 2011) project that from one-third to one-half of the 8 million hectares will be reseeded with RR®alfalfa by 2015, whilst others suggest that RR®alfalfa will occupy almost all the 8 to 9 million hectares in 10 years from now – this view is supported by the fact that farmer demand for RR®alfalfa in 2012 has been strong, because of the significant benefits it offers.

Benefits of RR®alfalfa include improved and more convenient weed control resulting in significant increases in quantity and quality of forage alfalfa as well as the crop and feed safety advantages that the product offers. Gene flow has been studied and 300 meters provides adequate isolation between conventional and biotech alfalfa and 500 meters for seed crops. RR®alfalfa plants were first produced in 1997 and field trials were initiated in 1999, followed with multiple location trials to determine the best performing varieties. Import approvals have already been secured for RR®alfalfa in major US export markets for alfalfa hay including Mexico, Canada, Japan, the Philippines and Australia – these countries represent greater than 90% of the US alfalfa hay export market. Japan is the major market for alfalfa hay exports, mainly from California and the west coast states. The USA is a major producer of alfalfa hay which occupies approximately 8 to 9 million hectares with an average yield of 7.59 metric tons per hectare of dry hay valued conservatively at US$105 per ton, worth US$7 billion per year. In addition, there is approximately 2 million hectares of alfalfa used for haylage/green chop with a yield of approximately 14.19 metric tons per hectare. The crop is sown in both the spring and the fall, with 1 to 4 cuttings per season, depending on location. Over 90% of the alfalfa in the USA is used for animal feed with about 7% used as sprouts for human consumption. Monsanto developed the biotech alfalfa in partnership with Forage Genetics International.

In addition to the four major biotech crops, soybean, maize, cotton and canola, and the RR®alfalfa and RR®sugarbeets, small hectarages of virus resistant squash (~2,000 hectares) and virus resistant papaya (~2,000 hectares) continued to be grown successfully in the USA in 2012. **In a landmark decision, Japan approved the import of biotech papaya from the US in 2011, for consumption as fresh fruit/food.** The biotech papaya is resistant to the papaya ring spot virus and commercialized in Hawaii, and was approved and been available in the US since 1997, sixteen years ago. The Japanese approval was granted and officially announced by Japan's Ministry of Agriculture, Forestry and Fisheries responsible for GM processed food quality labeling, Article 7 Clause 1 on GM fresh food quality labeling was amended on 31 August 2011 to include papaya as Japan's 8th GM imported food; the notification was effective 1 December 2011 (www.caa.go.jp/jas/hyoji/pdf/kijun_03.pdf). The list of approved biotech plant products in Japan now includes the following eight GM products: soybean, maize, potato, rape seed, cotton seed, alfalfa, sugarbeet and papaya. Walmart decided to market Bt sweetcorn in the US in 2012 because of the merits of the biotech crop over conventional; less insecticides, less insect damage and a higher quality product that contributes to sustainability.

In 2011, Dr. Aaron Gassmann, from Iowa State University, reported that western corn rootworm (WCR), had developed resistance to the single Bt protein Cry3Bb1 in four fields in Iowa (Gassman et al. 2011). More specifically resistance was found in Monsanto's YieldGard® VT Triple and Genuity® VT Triple PRO™ maize products. Monsanto reported that in 2011, both of these products continued to perform very well for growers, providing the expected level of rootworm control. The company reported that they are collaborating with Dr. Gassmann to ***"better understand his initial data and to determine if and how they impact our IPM recommendations to growers."*** The trait has been monitored since its launch in 2003 and a low incidence of rootworm has been detected annually in confined areas with high rootworm densities under particular environmental conditions. No measurable increase in the frequency of these occurrences has been detected over time. Collaboration between Dr. Gassmann and Monsanto aims to gain a better understanding of the issue with a view to developing recommendation for farmers. The development is a timely reminder that biotech crops, just like conventional crops, require to be carefully managed using good farming practices that include crop rotation, integrated pest management practices that require judicious deployment of refugia facilitated with new approaches such as "refuge in the bag" (RIB) and the deployment of maize with a dual mode of action for pest control, particularly in areas with high infestations. In summary, an effective strategy should feature prevention rather than cure, and always utilize multiple approaches to decrease the probability of the development of pest resistance which will always be a challenge in both conventional and biotech crops – the collaborative research initiated in 2011 was continued in 2012.

Benefits from Biotech Crops in the USA

In the most recent global study on the benefits from biotech crops, Brookes and Barfoot (2013, Forthcoming) estimated that USA has enhanced farm income from biotech crops by US$43.6 billion in the first sixteen years of commercialization of biotech crops 1996 to 2011. This represents 44% of global benefits for the same period, and the benefits for 2011 alone are estimated at US$8.8 billion (representing 45% of global benefits in 2011). These are the largest gains for any biotech crop country.

Professor of agricultural economics Carl Zulauf of the Ohio State University agricultural economics published two reports on the effects of biotechnology on the yield increase of three major crops: corn, soybeans, and cotton, and the effect of biotechnology on yield variation. The first report concluded that statistical evidence on linear yield trends show that biotechnology could play a role in escalating production. He studied the yield trends for corn, soybean, and cotton which are three of the most widely planted biotech crops in the U.S., and compared the trends with 11 other crops which are not yet commercialized as biotech products. The results of his evaluation showed that the 14 crops exhibited higher estimated yield trend from 1996-2011, the years when biotech varieties were already commercialized in the U.S. compared with the yield data of 1940-1995 when only conventional breeding techniques were used. "This analysis finds that, while the yield trend increased for all three biotech crops after 1996, the yield trend increased for less than half of the crops for which biotech varieties are of limited importance," Zulauf says. "This finding does not prove that biotechnology is the reason for the higher yield trend for corn, cotton and soybeans. It only reveals that the evidence on linear yield trends is not inconsistent with such a conclusion" (Zulauf and Hertzog, 2011a).

In another study, Prof. Zulauf studied biotechnology and variation in US yields to provide information concerning the commonly-expressed argument that biotechnology has reduced yield variability. The study revealed that in the 14 crops studied, the variation trend-line yield was lower during the biotech crop commercialization period of 1996-2011 compared to the earlier non-biotech period of 1940-1955. The difference in variability in the biotech and non-biotech crops is small. The authors believe that both biotech and traditional breeding methods have been equally successful at creating varieties that reduce yield variation. Since the decline in yield variability is permanent and not transitory, a more reliable supply reduces the size of stocks that need to be carried to assure an adequate supply and enhances the ability to expand non-food uses of crops (Zulauf and Hertzog, 2011b).

A 2010 University of Minnesota study (Hutchinson et al. 2010) on biotech maize, resistant to European corn borer (ECB) reported that ***"area-wide suppression dramatically reduced the estimated US$1 billion in annual losses caused by the European Corn Borer (ECB)."*** Importantly, the study reported that biotech Bt maize has even benefited conventional maize. Widespread planting of biotech Bt maize throughout the Upper Midwest of the USA since the 1996 has suppressed populations of the ECB, historically one of maize's primary pests causing losses estimated at approximately US$1 billion per year. Corn borer moths cannot discern between Bt and non-Bt maize, so the pest lays eggs in both Bt and non Bt maize fields. As soon as the eggs hatch in Bt maize, borer larvae feed and die within 24 to 48 hours. As a result, corn borer numbers have also declined in neighboring non-Bt fields by 28 percent to 73 percent in Minnesota, Illinois and Wisconsin. The study also reports similar declines of the pest in Iowa and Nebraska. The results of the study are consistent with the findings of Wu et al. (2008) who also demonstrated a dramatic up to 90%, area-wide reduction of cotton bollworm in China in other host crops such as maize, soybeans and vegetables.

In the US study, the economic benefits of this area-wide pest suppression was estimated at US$6.9 billion over the 14 year period 1996 to 2009 for the 5-state region, comprising

Minnesota, Illinois and Wisconsin, Iowa and Nebraska. Of the US$6.9 billion, it is noteworthy that non-Bt corn hectares accounted for US$4.3 billion (62 percent, or almost two-thirds, of the total benefit). The principal benefit of Bt maize is due to reduced yield losses, resulting from the deployment of Bt maize for which farmers have paid Bt maize technology fees. However, what is noteworthy is that as a result of area-wide pest suppression, farmers planting non-Bt hectares also experienced yield increases without the cost of Bt technology fees; in fact non-Bt hectares benefited from more than half (62%) of the total benefits of growing Bt maize in the 5 contiguous states.

Importantly, the study, noted that ***"previous cost-benefit analyses focused directly on Bt maize hectares but that this study was the first in the USA to include the value of area-wide pest suppression and the subsequent indirect benefits to farmers planting conventional non-Bt maize."*** The study did not consider benefits for other important Midwestern crops affected by European corn borer, such as sweet corn, potatoes and green beans, which the Wu study in China did. The authors noted ***"that additional environmental benefits from corn borer suppression are probably being realized, such as less insecticide use, but that these benefits have yet to be documented."***

It is noteworthy that the suppression of European corn borer was only demonstrable in Minnesota, Illinois and Wisconsin because state entomologists have monitored pest populations for more than 45 years. Pest suppression and related yield benefits may well be occurring to both adopters and non-adopters of Bt maize in other parts of the United States and the rest of the world, but those benefits cannot be documented due to lack of historical benchmark data on pest levels. In conclusion, the authors noted ***"that sustaining the economic and environmental benefits of Bt maize and other transgenic crops for adopters and non-adopters alike depends on the continued stewardship of these technologies. Thus, farmers, industry, and regulators need to remain committed to planting appropriate non-Bt maize refugia to minimize the risk that corn borers will develop resistance to Bt maize which has now been successfully planted on millions of hectares globally since 1996."*** In summary, this important study confirms that Bt maize delivers more benefits to society than originally realized and is consistent with similar indirect benefits in China from the deployment of Bt cotton.

An independent study published by the US National Research Council (2010) (an organization related to the National US Academy of Sciences) in April 2010 is entitled ***"The impact of genetically engineered (GE) crops on farm sustainability in the United States."*** The study concluded that ***"many US farmers are realizing substantial economic and environmental benefits, such as lower production cost benefits, fewer pest problems, reduced use of pesticides and better yields compared with conventional crops."*** Whereas the study documents the decreased use of pesticides, and that GE farmers are more likely to practice conservation tillage, it opines that the improvement in water quality might prove to be the largest single benefit associated with biotech crops. The study concluded that farmers have not been adversely affected by the proprietary terms involved in patent protected GE seed. The study also noted that biotech crops ***"tolerant to glyphosate could develop more weed problems as weeds evolve their own resistance to glyphosate and that herbicide crops could loose their effectiveness unless farmers also use other proven weed and insect management practices."*** The study claims to be ***"the first comprehensive assessment of how GE crops are affecting all US farmers including those who grow conventional or organic crops."***

A study by Piggott and Marra (2007) of 2005 data in North Carolina, USA assessed the additional per hectare benefits to a farmer and to the state of North Carolina resulting from a change in policy for Bollgard®II cotton that would eliminate the required refuge. The annual benefit at the farm level was US$56.37 per hectare and US$32,202,907 at the state level for North Carolina, when non-pecuniary benefits are not considered. When non-pecuniary benefits are considered, the benefits per hectare were US$66.44 at the farm level and US$37,986,449 at the state level, which is an increase of US$10.07 per hectare and US$5,783,542 at the state level. The increase in value to the technology developer was US$2,427,620.

A study by the University of Arizona (Frisvold et al. 2006) examined the impact of Bt cotton in the USA and China in 2001. The two countries increased total world cotton production by 0.7% and reduced world cotton price by US$0.31 per kg. Net global economic effects were US$838 million worldwide with consumers benefiting US$63 million. Chinese cotton farmers gained US$428 million and US farmers gained US$179 million whereas cotton farmers in the rest of the world lost US$69 million because of the reduced price of cotton.

Political Will and Support for Biotech Crops in the US

On January 24, 2012, US President Barrack Obama in his State of the Union address challenged his fellow countrymen to see a future where they are in control of their own energy and to have an economy that is **"built to last"**. In response, Jim Greenwood, President and CEO of the Biotechnology Industry Organization (BIO), stated that biotechnology can meet the challenge of the President to create such economy. He noted that the biotech industry continues to provide high-wage and high-value jobs and at the same time **biotechnology drives U.S. leadership in competitiveness and innovation**. More importantly, he stressed that biotechnology offers very significant scientific breakthroughs in disease treatment, alternative energy sources, hunger alleviation, and protection against bio-terrorism. ***"Realizing the promise of biotechnology requires a comprehensive national strategy that fine-tunes some policies and overhauls others. The biotechnology sector continues to stand ready to work with President Obama, his Administration and the Congress to help create jobs and drive economic growth,"*** said Greenwood (Crop Biotech Update, 27 January 2012).

US Secretary of State Jose Fernandez reaffirmed the government's support to agricultural biotechnology as a tool for food security by saying that ***"biotech can help produce more food using resources such as land, water, fertilizer and pesticide."*** Fernandez also mentioned that ***"the U.S. works with other governments around the world to promote science-based regulatory systems. The U.S. will also put initiative on public outreach to prevent and eliminate misinformation on agri-biotech"*** (Crop Biotech Update, 23 March 2012).

The Secretary of the US Department of Agriculture, Tom Vilsack, addressed the American Seed Trade Association's 129th Annual Convention regarding the need for the seed industry to help educate the policy makers in the capital about the importance of agricultural research, and to farmers about coexistence. He highlighted the importance of research and innovation in helping farmers adapt to climate change and be more efficient with resources such as water, nitrogen and fertilizer. He also opined that as science changes and advances, the regulatory framework needs to follow. On genetic engineering (GE) Vilsack said that ***"the United States is a large country and there are vast land holdings that can use GE, conventional, and organic at the same time. Farmers should be able to choose the production method they want. All aspects of agriculture must be tapped to make it an interesting and attractive endeavor. Seed industries should be there to help the country, and the farmers realize this"*** (Crop Biotech Update, 22 June 2012).

Aside from the impact of the 2012 drought on U.S. planting of corn and soybean, drought has affected volatility of global prices and agricultural productivity. The 2003 World Food Prize Laureate Catherine Bertini, together with former USDA secretary Dan Glickman, called for support for agricultural research and technologies that will help equip farmers with the necessary knowledge and tools to face severe drought in the fields. ***"We should increase support for the agricultural researchers, in the U.S. and around the world, who are developing remarkable new drought and flood tolerant crop varieties. The results of this research will be essential if the agricultural sector is to continue to meet food demand in the face of weather variability,"*** said Bertini and Glickman (Crop Biotech Update, 10 August 2012).

Importantly, The American Medical Association (AMA) released a statement reiterating its position on genetically modified crops (Crop Biotech Update, 26 September 2012). It continues to recognize the conclusions of the 1987 National Academy of Sciences white paper that:

- There is no evidence that unique hazards exist either in the use of rDNA techniques or in the movement of genes between unrelated organisms;
- The risks associated with the introduction of rDNA-engineered organisms are the same in kind as those associated with the introduction of unmodified organisms and organisms modified by other methods;
- Assessment of the risk of introducing rDNA-engineered organisms into the environment should be based on the nature of the organism and the environment into which it is introduced, not on the method by which it was produced.

During the last two years, the Gates Foundation has strengthened its support for GM crops. Recently it approved a US$10 million grant to the John Innes Institute in the United Kingdom (BBC News Online, 15 July 2012) to focus on nitrogen fixation for major staples of rice, wheat and maize.

Regulation is the Biggest Constraint to Adoption

California's Proposition 37 or the GMO labelling initiative appeared on voter ballots for the November 6 elections. Those opposed to the law believe that the poll was a tactic to scare consumers of the safety of GM products. Biotech labeling, which has been adopted in more than 40 countries, has never been endorsed by the FDA. The agency says crops engineered to tolerate herbicides or produce insecticide pose no greater health risks than conventional foods (Bloomberg, 2 May 2012).

A study by Alston and Sumner (Reuters, 16 Sept 2012) estimated that, if passed, the cost of implementing Proposition 37 for GM food labeling in Calfiornia would have been US$1.2 billion – in the view of the study "a costly regulation with no benefits." The extra direct and indirect costs to farmers and the food industry, some of which would have been passed on to consumers, involved additional services that would have been required to meet a threshold of 0.5% by 2014 and an impractical zero tolerance by 2019. About 40 countries require GM food labeling for thresholds ranging from 0.9% to 5% but in practice enforcement is problematic, particularly in Europe.

It is noteworthy that on 6 November 2012, in California, USA, voters defeated Proposition 37, the proposed state petition on "Mandatory Labeling of Genetically Engineered Food Initiative" – with the final result of No 53.7% and Yes 46.3% (Crop Biotech Update, 14 November 2012).

Two reviews were made by the European Food Safety Authority, one released on October and another in 28 November 2012, on a publication by Seralini et al. (2012), and determined that the conclusion drawn by the authors in the publication could not be supported by the data presented. The self explanatory EFSA abstract of its review (EFSA, 2012) is reproduced in its entirety in the chapter on European Union which states that, ***"Considering that the study as reported in the Séralini et al, (2012) publication is of inadequate design, analysis and reporting, EFSA finds that it is of insufficient scientific quality for safety assessment. Therefore EFSA, concludes that the Séralini et al, study as reported in the 2012 publication does not impact the ongoing re-evaluation of glyphosate, and does not see a need to reopen the existing safety evaluation of maize NK603 and its related stacks"*** (Crop Biotech Update, 10 October and 5 December 2012).

Expediting the Regulation Process of Biotech Crops in the US

On February 22, 2012, the U.S. Department of Agriculture's Deputy Administrator, Michael Gregoire, announced that the process of biotech crop approval will be made more efficient. In the 1990s, the process only took six months but this has lengthened to three years due to increased public interest in the subject and the introduction of national organic food standards. The move was in response to the issues raised by American Soybean Association CEO, Steve Censky, that U.S. farmers are disadvantaged compared to farmers in other countries like Brazil, which have a faster time of approval. ***"We can improve the quality of decisions by providing for this earlier public input in the process,"*** Gregoire said. ***"We are not sacrificing quality at all. The Congress is helping to speed crop reviews by increasing APHIS's budget for biotech regulation to a record US$18 million this year, from US$13 million in 2011,"*** Gregoire added (Crop Biotech Update, 2 March 2012). The APHIS guideline was published in the Federal Register on 6 March 2012 at http://www.aphis.usda.gov/brs/fedregister/BRS_20120306.pdf.

12 New GM Crops were submitted for USDA approval – 9 were fast-tracked under new permitting rules and 3 were under the old system. In August 2012, USDA posted twelve new GE crops for public comment with a September 11 deadline, nine of which are in the new fast-track process, designed to cut in half the time approving GE seeds and crops to enter the market from 3 years to 18 months. Three of the new biotech crops were under the old petition process which requires 60-day public comment period. The three crops under the old process were:

1. **Dow 2,4-D and Glufosinate Tolerant Soybean,**
2. **Bayer Glyphosate and Isoxaflutole Tolerant Soybean**
3. **Syngenta Corn Rootworm Resistant Corn**

As of November 6, 2012, no decisions were made.
(http://www.aphis.usda.gov/biotechnology/not_reg.html)

The 9 additional new crops for public comment apply to the petitions for non-regulated status which include information submitted by the petitioning company. Once USDA has completed their environmental analyses they will open a final 30-day comment period for the decision-making documents. The 9 crops under the new process with the same September 11 deadline are:

1. **Okanagan Non-Browning Apple**
2. **Dow 2,4-D, Glyphosate and Glufosinate tolerant Soybean**
3. **Monsanto Dicamba Tolerant Soybean**
4. **BASF Imidazolinone Tolerant Soybean**
5. **Monsanto High Yield Soybean**
6. **Monsanto Glyphosate Tolerant Canola**
7. **Pioneer Glyphosate Tolerant Canola**
8. **Monsanto Hybrid Corn**
9. **Genective Glyphosate Tolerant Corn**

As of November 6, 2012, no decisions were made.
(http://www.aphis.usda.gov/biotechnology/not_reg.html)

USDA notes that the new fast-track process allows for earlier input from the public to improve the quality of its environmental analyses. According to a USDA press release, the new process is a part of efforts by the Secretary of Agriculture, Tom Vilsack, to **"transform USDA into a high-performing organization that focuses on its customers"** (http://www.aphis.usda.gov/newsroom/2011/11/ge_petition_process.shtml).

Brief Chronological Overview of crop biotech related events in the USA in 2012 reported in ISAAA's weekly Crop Biotech Update (CBU), where original reference is provided:

1. The Cotton Genetics Research Award for 2011 was awarded to Keerti Rathore, for reducing the level of gossypol in cottonseed. The GM cotton renders the protein-rich seed, fit for human and monogastric animal consumption while maintaining normal levels of gossypol and related chemicals in other plant parts for insect and pathogen protection (Crop Biotech Update, 13 January 2012).

2. A survey of US alfalfa growers conducted by Daniel H. Putnam and Steve Orloff in 2011 found that of 381 respondents, almost one-third, or 113, had grown herbicide tolerant (HT) alfalfa, and more than 90% of the biotech alfalfa growers said that they were highly satisfied with the technology, citing efficient weed management as its best (Crop Biotech Update, 27 January 2012).

3. A study conducted by the United Soybean Board (USB) showed that 61 percent of health care professionals in the United States view biotechnology as a way to increase food production, and identified positive health and agriculture attributes of soybean, such as low saturated fat content in food products and reduced use of pesticides and herbicides in farming (Crop Biotech Update, 27 April 2012).

4. Scientific Analyst Victor Haroldsen reported that grafting a transgenic fruit tree rootstock with a conventional wild-type scion, was the most promising GE technology for fruit and nut crops for conferring resistance to pests and diseases (Crop Biotech Update, 3 February 2012).

5. The International Food Information Council (IFIC) revealed the March 2012 survey results on consumers' perception of food technology, where 77% of the respondents would likely to purchase food produced through biotechnology, 76% were satisfied with the existing federal rules on food labeling and 66% of the respondents claimed that they were satisfied

with the current policy of Food and Drug Administration for labeling of food produced using biotechnology (Crop Biotech Update, 11 May 2012).

Farmer Experience

Laura Foell, a United Soybean Board director and a farmer from Iowa, said, ***"As a parent and a farmer, I chose biotechnology because I wanted my kids eating safe, nutritious foods. After all, our vegetable garden for the family's meals is right next to our soybean fields, so it was important to reduce my farm's pesticide use. Biotechnology cut it by half"*** (Foell, 2010).

Illinois Soybean Association Chairman and Roseville Farmer **Ron Moore** in his speech at a biotechnology conference in Chicago in 2010 said that, ***"the advancements in biotechnology have drastically changed the agricultural industry in the past decade, especially the seed trade. Corn and soybeans can now be genetically engineered to be herbicide resistant, insect resistant and drought resistant. Drought tolerant is big,"*** he said. ***"You can grow in more arid areas. It allows us to bring new traits to market quicker"*** (Moore, 2010).

BRAZIL

In 2012, Brazil reached, for the fourth consecutive year, the largest increase of biotech crops area in any country in the world. Brazilian farmers sowed ~36.6 million hectares of biotech crops, including soybean, maize and cotton, a record year-over-year increase of ~6.3 million hectares in comparison with 2011. The total sowed area of these three crops in Brazil was 44.7 million hectares of which ~36.6 million hectares or ~82% was biotech. Brazil is still the second country in terms of biotech crop hectarage (US is the leader) and in 2012, it further enhanced its status by consolidating its position and decreasing the gap between it and the US, specially soybean and maize. Brazil grew 21% of the global biotech crop hectarage of 170.3 million hectarage of biotech crops globally in 2012. GM soybean by far leads the three Brazilian biotech crops, in hectarage, 23.9 million hectares, up from ~20.7 million hectares in 2011, equivalent to an impressive year-over-year growth of 15.4%. Biotech soybean occupied 88% of the 27.14 million hectares of the national soybean crop grown in Brazil in 2012. GM maize remained the second most important crop in Brazil with a total of 12.1 million hectares for both summer and winter (summer

5.2 million hectares and winter 6.9 million hectares), up by 3 million hectares from 9.1 million hectares, or a substantial ~33% from 2011. All three categories of events IR, HT, and the stack of IR/HT are deployed in both summer and winter maize. The third and last biotech crop in Brazil is cotton, which was sowed on 1.1 million hectares in 2012 of which 0.55 million hectares or 50.1% was biotech cotton. This GM crop decreased from 0.6 million hectares in 2011 to 0.5 million hectares in 2012, -9.8%. In 2011, Brazil approved a biotech bean that is resistant to the golden bean mosaic virus. EMBRAPA plans to commercialize this homegrown biotech GM bean in 2014/15 season. The economic benefits to Brazil from biotech crops for sixteen years period (2003 to 2011) is US$6.6 billion and US$2 billion for 2011 alone. Brazil is quickly emerging as the engine of growth, not only in Latin America, but in the world with increased activities in Africa.

BRAZIL

Population: 194.2 million

GDP: US$1,575 billion

GDP per Capita: US$8,210

Agriculture as % GDP: 7%

Agricultural GDP: US$110 billion

% employed in agriculture: 21%

Arable Land (AL): 59.6 million hectares

Ratio of AL/Population*: 1.3

Major crops:
- Sugarcane
- Cassava
- Soybean
- Oranges
- Maize

Commercialized Biotech Crops:
- HT Soybean
- Bt Cotton
- Bt/HT Maize

Total area under biotech crops and (%) increase in 2012:
36.6 Million Hectares (+21%)

Farm income gain from biotech, 2003-2011: US$6.6 billion

*Ratio: % global arable land / % global population

The first crop estimate for 2012-2013 from CONAB (the Brazilian agency for crop surveys), project that following good returns for the last three seasons, Brazilian farmers are expected to plant a record 52.2 million hectares in the 2012/13 crop year, an increase of 2.7% in planted area over the last season.

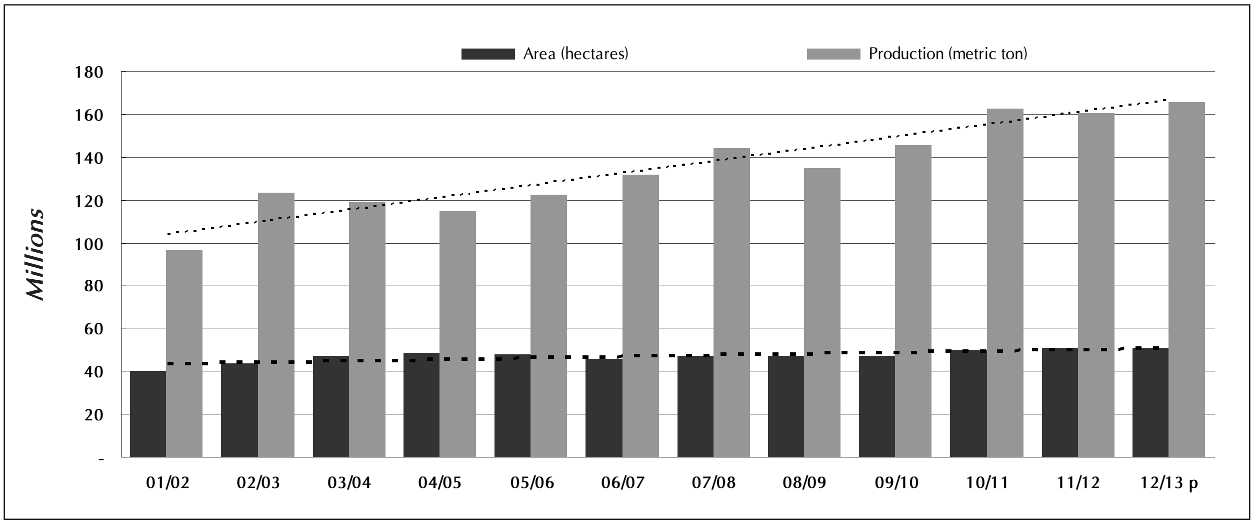
In view of the expansion in planted areas and yield projections, CONAB predicts that total grain production will reach 182.3 million tons, an increase of 10%, compared to the great 2011/12 crop season (Figure 5). Between 2002/03 and 2011/12, harvested crop area in Brazil increased from 43.95 million hectares to 51.25 million hectares, an annual growth of 1.5%. In this period, the crops that occupied the biggest increase in hectarage increases were soybeans (+6.6 million ha), winter maize (+2.4 million ha) and cotton (+0.75 million ha), exactly three crops with GM traits in Brazil. The crops that suffered a decrease in hectarage during the same period were summer maize (-1.17 million ha), crop which have large adoption of GM traits, edible beans (-0.44 million ha – the GM edible bean with a virus resistance could change this decrease), and rice (-0.38 million ha).

In addition to the substantial economic benefits from crops in Brazil, the yield gains from improved crops are important for sustainable production on crop land, and the conservation of natural resources, for future generations.

As a result of consistent gains in yield, total grain production between 2002/03 and 2011/12 increased from 123.2 million tons to 160.3 million tons, an annual growth of 2.7%. These gains in yield have made important contributions to Brazilian agriculture which has been one of the most dynamic sectors in the Brazilian economy, and one of the principal drivers of the thriving Brazilian economy, including significant export earnings. Agriculture and more specifically improved crop production have also protected the domestic economy from the global financial crises during the last couple of years.

In 2012, Brazil reached, in the fourth consecutive year, the largest increase of biotech crops area in any country in the world. Brazilian farmers sowed ~36.6 million hectares of biotech crops, including soybean, maize and cotton, a record year-over-year increase, 6.3 million hectares in comparison

Figure 5. Total Grain Sowed Area and Production in Brazil



Source: CONAB | Elaboration: CÉLERES®.

with 2011. The total sowed area of those three crops in Brazil was 44.7 million hectares of which ~36.6 million hectares or 81.9% was biotech. Brazil is still the second country in terms of biotech crop hectarage (US is the leader) and in 2012, it further enhanced its status by consolidating its position and decreasing the gap between it and the US, specially in soybean and maize. Brazil grew 21% of the global biotech crop hectarage of 170.3 million hectarage of biotech crops globally in 2011. GM soybean occupies, by far, the leadership of the three Brazilian biotech crops, in hectarage, 23.9 million hectares, up from 20.7 million hectares in 2011, equivalent to an impressive year-over-year growth of 15.4%. Biotech soybean occupied 88% of the 27.4 million hectares of the national soybean crop grown in Brazil in 2012 (Table 4). The highest adoption rate, by region, in the three regions was the South region with 90.7% (within which Rio Grande do Sul was the highest at 98.9% adoption) followed by the Southeast at 88.5% and MidWest at 88.2%.

GM maize remained the second most important crop in Brazil with a total of 12.1 million hectares for both summer and winter (summer 5.13 million hectares and winter 6.93 million hectares), up by 3 million hectares from 9.1 million hectares or a substantial ~33% from 2011. All three categories of events IR, HT, and the stack of IR/HT are deployed in both summer and winter maize. In Brazil, summer and winter maize crops are discussed separately, due to many differences between the managements during the crop season. Respective details can be viewed in Tables 5 to 7. Of the 8.27 million hectares of summer maize, 5.17 million hectares or 62.5% are biotech, of which 53.2% is IR, 29.7% as IR/HT stack, and 7.5% as HT alone. The highest adoption, by region, is in the Southeast at 88.1%, MidWest at 86.6% and South at 86.4%. On the other hand, winter maize (also referred to as "second season maize crop", "safrinha") occupies a smaller hectarage than summer maize at 7.9 million hectares, and biotech winter maize is responsible for 6.93 million hectares or 87.7%, which 48.9% is the stacked product IR/HT, 40.7% is IR and 10.4% as herbicide tolerance alone. The highest adoption, by region is in the South at 91.6%, followed by MidWest at 90.5% and Southeast, 89.7%.

The third and last biotech crop in Brazil is cotton, was sowed on 1.1 million hectares in 2012 of which 0.55 million hectares or 50.1% was biotech cotton (Table 8). This GM crop decreased from 0.6 million hectares in 2011 to 0.5 million hectares in 2012. Of these 0.5 million hectares of biotech cotton, 52.7% is the HT, 29% is IR and 18.2% is the stacked trait, IR/HT. The highest adoption, by region is in the North at 100%, followed by the Northeast 58.5% and the North/Northeast at 57.1%.

In 2012/13, 88.1% of the area grown with soybeans, 87.8% of the area with maize (winter season crop), 62.5% of the area with maize (summer season crop) and 50.1% of cotton, will be planted with biotech traits (Figure 6).

The analysis of the traits in use in Brazil shows that herbicide tolerance (HT) is the most adopted trait, with 25.3 million hectares, followed by insect resistance (IR) with 5.7 million hectares and lastly,

Table 4. Soybean Biotech Adoption in Brazil for 2012

	Area (Million ha)	Productivity (Tons/ha)	Production (Million tons)	Adoption rate (% of total area)				Area with biotech crops (million ha)			
				IR	HT	IR/HT	Total	IR	HT	IR/HT	Total
NORTH	**0.78**	**3.03**	**2.37**	**0.0%**	**65.6%**	**0.0%**	**65.6%**	**0.00**	**0.51**	**0.00**	**0.51**
NORTHEAST	**2.40**	**3.09**	**7.40**	**0.0%**	**83.4%**	**0.3%**	**83.7%**	**0.00**	**2.00**	**0.01**	**2.01**
Maranhão	0.65	3.13	2.02	0.0%	76.5%	0.0%	76.5%	0.00	0.49	0.00	0.49
Piauí	0.49	2.94	1.43	0.0%	72.9%	0.0%	72.9%	0.00	0.35	0.00	0.35
Bahia	1.27	3.12	3.96	0.0%	91.0%	0.6%	91.6%	0.00	1.15	0.01	1.16
SOUTHEAST	**1.92**	**2.91**	**5.59**	**0.0%**	**88.2%**	**0.3%**	**88.4%**	**0.00**	**1.69**	**0.01**	**1.70**
Minas Gerais	1.25	3.08	3.84	0.0%	87.2%	0.3%	87.4%	0.00	1.09	0.00	1.09
São Paulo	0.67	2.61	1.75	0.0%	90.0%	0.3%	90.3%	0.00	0.60	0.00	0.61
SOUTH	**9.69**	**2.58**	**25.01**	**0.0%**	**90.7%**	**0.1%**	**90.8%**	**0.00**	**8.79**	**0.01**	**8.79**
Paraná	4.75	2.89	13.74	0.0%	82.4%	0.1%	82.5%	0.00	3.91	0.00	3.92
Santa Catarina	0.49	2.85	1.40	0.0%	97.2%	0.0%	97.2%	0.00	0.48	0.00	0.48
Rio Grande do Sul	4.45	2.22	9.87	0.0%	98.8%	0.1%	98.9%	0.00	4.40	0.00	4.40
MIDWEST	**12.35**	**3.05**	**37.73**	**0.0%**	**88.0%**	**0.1%**	**88.1%**	**0.00**	**10.87**	**0.02**	**10.89**
Mato Grosso	7.50	3.12	23.37	0.0%	86.0%	0.2%	86.2%	0.00	6.45	0.01	6.46
Mato Grosso Sul	1.98	2.69	5.34	0.0%	88.0%	0.1%	88.1%	0.00	1.75	0.00	1.75
Goiás	2.81	3.13	8.80	0.0%	93.2%	0.2%	93.3%	0.00	2.62	0.00	2.62
Distrito Federal	0.06	3.39	0.21	0.0%	93.2%	0.0%	93.2%	0.00	0.06	0.00	0.06
NORTH/ NORTHEAST	**3.18**	**3.07**	**9.78**	**0.0%**	**79.0%**	**0.2%**	**79.3%**	**0.00**	**2.52**	**0.01**	**2.52**
MIDSOUTH	**23.96**	**2.85**	**68.33**	**0.0%**	**89.1%**	**0.1%**	**89.2%**	**0.00**	**21.35**	**0.03**	**21.38**
BRAZIL	**27.14**	**2.88**	**78.10**	**0.0%**	**87.9%**	**0.1%**	**88.1%**	**0.00**	**23.86**	**0.04**	**23.90**

Source: CÉLERES®.

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Table 5. Biotech Corn (Summer and Winter) Adoption in Brazil for 2012

	Area (Million ha)	Productivity (Tons/ha)	Production (Million tons)	Adoption rate (% of total area)				Area with biotech crops (million ha)			
				IR	HT	IR/HT	Total	IR	HT	IR/HT	Total
NORTH	**0.56**	**2.56**	**1.42**	**7.1%**	**2.1%**	**3.8%**	**13.0%**	**0.04**	**0.01**	**0.02**	**0.07**
NORTHEAST	**3.29**	**1.74**	**5.71**	**17.1%**	**3.0%**	**11.5%**	**31.7%**	**0.56**	**0.10**	**0.38**	**1.04**
Maranhão	0.50	1.74	0.88	34.6%	5.1%	21.4%	61.1%	0.17	0.03	0.11	0.31
Piauí	0.36	1.76	0.64	34.0%	4.9%	19.2%	58.1%	0.12	0.02	0.07	0.21
Bahia	0.86	2.71	2.32	25.5%	5.3%	21.5%	52.3%	0.22	0.04	0.18	0.45
SOUTHEAST	**2.08**	**5.88**	**12.20**	**46.3%**	**7.5%**	**34.4%**	**88.2%**	**0.96**	**0.16**	**0.72**	**1.83**
Minas Gerais	1.09	6.41	7.01	51.5%	6.5%	29.0%	87.0%	0.56	0.07	0.32	0.95
São Paulo	0.93	5.40	5.02	39.7%	8.4%	41.4%	89.4%	0.37	0.08	0.39	0.83
SOUTH	**4.72**	**5.71**	**26.97**	**40.8%**	**7.0%**	**40.9%**	**88.7%**	**1.93**	**0.33**	**1.93**	**4.19**
Paraná	3.04	6.09	18.49	39.3%	7.8%	43.0%	90.0%	1.19	0.24	1.30	2.73
Santa Catarina	0.58	6.39	3.71	43.5%	6.8%	37.2%	87.4%	0.25	0.04	0.22	0.51
Rio Grande do Sul	1.11	4.32	4.77	43.6%	5.1%	37.1%	85.7%	0.48	0.06	0.41	0.95
MIDWEST	**5.51**	**5.47**	**30.15**	**37.7%**	**9.3%**	**43.2%**	**90.2%**	**2.08**	**0.51**	**2.38**	**4.97**
Mato Grosso	3.24	5.65	18.32	37.8%	9.8%	43.6%	91.2%	1.22	0.32	1.41	2.96
Mato Grosso Sul	1.27	4.11	5.22	36.6%	9.0%	42.5%	88.1%	0.46	0.11	0.54	1.12
Goiás	0.97	6.52	6.34	38.8%	8.2%	42.6%	89.6%	0.38	0.08	0.41	0.87
Distrito Federal	0.03	8.77	0.27	39.2%	6.7%	42.2%	88.0%	0.01	0.00	0.01	0.03
NORTH/ NORTHEAST	**3.84**	**1.85**	**7.13**	**15.7%**	**2.9%**	**10.4%**	**29.0%**	**0.60**	**0.11**	**0.40**	**1.11**
MIDSOUTH	**12.31**	**5.63**	**69.32**	**40.3%**	**8.1%**	**40.8%**	**89.3%**	**4.97**	**1.00**	**5.02**	**10.99**
BRAZIL	**16.15**	**4.73**	**76.45**	**34.5%**	**6.9%**	**33.6%**	**74.9%**	**5.57**	**1.11**	**5.42**	**12.10**

Source: CÉLERES®.

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Table 6. Biotech Summer Corn Adoption in Brazil for 2012

	Area (Million ha)	Productivity (Tons/ha)	Production (Million tons)	Adoption rate (% of total area)				Area with biotech crops (million ha)			
				IR	HT	IR/HT	Total	IR	HT	IR/HT	Total
NORTH	**0.51**	**2.54**	**1.30**	**7.1%**	**1.9%**	**2.8%**	**11.9%**	**0.04**	**0.01**	**0.01**	**0.06**
NORTHEAST	**2.83**	**1.80**	**5.10**	**17.2%**	**2.6%**	**9.6%**	**29.5%**	**0.49**	**0.07**	**0.27**	**0.84**
Maranhão	0.49	1.80	0.88	34.5%	4.9%	20.7%	60.2%	0.17	0.02	0.10	0.29
Piauí	0.35	1.81	0.64	33.9%	4.8%	18.5%	57.2%	0.12	0.02	0.07	0.20
Bahia	0.43	4.02	1.72	35.9%	5.1%	20.9%	61.9%	0.15	0.02	0.09	0.27
SOUTHEAST	**1.68**	**6.35**	**10.69**	**48.5%**	**7.1%**	**32.3%**	**87.9%**	**0.82**	**0.12**	**0.54**	**1.48**
Minas Gerais	1.04	6.39	6.62	52.4%	6.3%	28.2%	86.9%	0.54	0.07	0.29	0.90
São Paulo	0.60	6.55	3.90	41.1%	8.0%	40.0%	89.2%	0.24	0.05	0.24	0.53
SOUTH	**2.57**	**6.20**	**15.93**	**43.9%**	**5.5%**	**36.8%**	**86.2%**	**1.13**	**0.14**	**0.95**	**2.22**
Paraná	0.89	8.42	7.45	44.7%	5.2%	36.1%	86.0%	0.40	0.05	0.32	0.76
Santa Catarina	0.58	6.39	3.71	43.5%	6.8%	37.2%	87.4%	0.25	0.04	0.22	0.51
Rio Grande do Sul	1.11	4.32	4.77	43.6%	5.1%	37.1%	85.7%	0.48	0.06	0.41	0.95
MIDWEST	**0.67**	**7.38**	**4.92**	**42.0%**	**6.6%**	**39.0%**	**87.6%**	**0.28**	**0.04**	**0.26**	**0.58**
Mato Grosso	0.14	6.20	0.87	44.0%	7.0%	33.4%	84.4%	0.06	0.01	0.05	0.12
Mato Grosso Sul	0.09	8.00	0.72	42.9%	6.8%	37.1%	86.8%	0.04	0.01	0.03	0.08
Goiás	0.41	7.53	3.11	41.3%	6.5%	41.2%	88.9%	0.17	0.03	0.17	0.37
Distrito Federal	0.02	9.54	0.22	40.2%	6.3%	41.5%	88.0%	0.01	0.00	0.01	0.02
NORTH/ NORTHEAST	**3.35**	**1.91**	**6.41**	**15.7%**	**2.5%**	**8.6%**	**26.8%**	**0.53**	**0.08**	**0.29**	**0.90**
MIDSOUTH	**4.92**	**6.41**	**31.54**	**45.2%**	**6.2%**	**35.5%**	**87.0%**	**2.22**	**0.31**	**1.75**	**4.28**
BRAZIL	**8.27**	**4.59**	**37.95**	**33.3%**	**4.7%**	**24.6%**	**62.6%**	**2.75**	**0.39**	**2.03**	**5.17**

Source: CÉLERES®.

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Table 7. Biotech Winter Corn Adoption in Brazil for 2012

	Area (Million ha)	Productivity (Tons/ ha)	Production (Million tons)	Adoption rate (% of total area)				Area with biotech crops (million ha)			
				IR	HT	IR/HT	Total	IR	HT	IR/HT	Total
NORTH	**0.04**	**2.83**	**0.12**	**7.8%**	**3.5%**	**14.8%**	**26.1%**	**0.00**	**0.00**	**0.01**	**0.01**
NORTHEAST	**0.45**	**1.33**	**0.60**	**16.4%**	**5.6%**	**23.3%**	**45.3%**	**0.07**	**0.03**	**0.11**	**0.21**
Maranhão	0.02	0.00	0.00	37.5%	9.9%	44.1%	91.5%	0.01	0.00	0.01	0.01
Piauí	0.01	0.00	0.00	37.5%	9.9%	44.1%	91.5%	0.00	0.00	0.00	0.01
Bahia	0.43	1.40	0.60	15.2%	5.4%	22.1%	42.7%	0.07	0.02	0.09	0.18
SOUTHEAST	**0.39**	**3.84**	**1.51**	**36.9%**	**9.1%**	**43.7%**	**89.7%**	**0.15**	**0.04**	**0.17**	**0.35**
Minas Gerais	0.06	6.60	0.39	36.1%	9.4%	43.0%	88.5%	0.02	0.01	0.03	0.05
São Paulo	0.34	3.36	1.12	37.1%	9.0%	43.9%	89.9%	0.12	0.03	0.15	0.30
SOUTH	**2.15**	**5.13**	**11.04**	**37.1%**	**8.8%**	**45.8%**	**91.6%**	**0.80**	**0.19**	**0.98**	**1.97**
Paraná	2.15	5.13	11.04	37.1%	8.8%	45.8%	91.6%	0.80	0.19	0.98	1.97
Santa Catarina	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	0.00	0.00	0.00	0.00
Rio Grande do Sul	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	0.00	0.00	0.00	0.00
MIDWEST	**4.85**	**5.20**	**25.23**	**37.1%**	**9.7%**	**43.7%**	**90.5%**	**1.80**	**0.47**	**2.12**	**4.39**
Mato Grosso	3.10	5.63	17.45	37.5%	9.9%	44.1%	91.5%	1.16	0.31	1.37	2.84
Mato Grosso Sul	1.18	3.81	4.50	36.1%	9.2%	42.9%	88.2%	0.43	0.11	0.51	1.04
Goiás	0.56	5.77	3.23	37.1%	9.5%	43.5%	90.1%	0.21	0.05	0.24	0.50
Distrito Federal	0.01	6.38	0.05	36.1%	8.1%	44.1%	88.3%	0.00	0.00	0.00	0.01
NORTH/ NORTHEAST	**0.50**	**1.46**	**0.72**	**15.7%**	**5.5%**	**22.5%**	**43.7%**	**0.08**	**0.03**	**0.11**	**0.22**
MIDSOUTH	**7.39**	**5.11**	**37.78**	**37.1%**	**9.4%**	**44.3%**	**90.8%**	**2.74**	**0.69**	**3.28**	**6.71**
BRAZIL	**7.89**	**4.88**	**38.50**	**35.7%**	**9.1%**	**43.0%**	**87.8%**	**2.82**	**0.72**	**3.39**	**6.93**

Source: CÉLERES®.

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Table 8. Biotech Cotton Adoption in Brazil for 2012

	Area (Million ha)	Productivity (Tons/ ha)	Production (Million tons)	Adoption rate (% of total area)				Area with biotech crops (million ha)			
				IR	HT	IR/HT	Total	IR	HT	IR/HT	Total
NORTH	**0.01**	**3.58**	**0.01**	**17.7%**	**29.5%**	**11.8%**	**59.0%**	**0.00**	**0.00**	**0.00**	**0.01**
NORTHEAST	**0.41**	**1.50**	**0.57**	**17.7%**	**29.1%**	**11.8%**	**58.5%**	**0.07**	**0.12**	**0.05**	**0.24**
Maranhão	0.02	1.49	0.03	17.7%	29.5%	11.8%	59.0%	0.00	0.01	0.00	0.01
Piauí	0.02	1.32	0.03	17.7%	29.5%	11.8%	59.0%	0.00	0.01	0.00	0.01
Bahia	0.36	1.56	0.51	17.7%	29.5%	11.8%	59.0%	0.06	0.11	0.04	0.21
SOUTHEAST	**0.03**	**1.43**	**0.04**	**24.8%**	**12.5%**	**12.5%**	**49.8%**	**0.01**	**0.00**	**0.00**	**0.01**
Minas Gerais	0.02	1.46	0.03	24.8%	12.5%	12.5%	49.8%	0.00	0.00	0.00	0.01
São Paulo	0.01	1.33	0.01	24.8%	12.5%	12.5%	49.8%	0.00	0.00	0.00	0.00
SOUTH	**0.00**	**0.79**	**0.00**	**10.5%**	**10.5%**	**9.0%**	**30.0%**	**0.00**	**0.00**	**0.00**	**0.00**
Paraná	0.00	0.79	0.00	10.5%	10.5%	9.0%	30.0%	0.00	0.00	0.00	0.00
Santa Catarina	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	0.00	0.00	0.00	0.00
Rio Grande do Sul	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	0.00	0.00	0.00	0.00
MIDWEST	**0.64**	**1.33**	**0.89**	**12.3%**	**25.1%**	**7.3%**	**44.7%**	**0.08**	**0.16**	**0.05**	**0.29**
Mato Grosso	0.52	1.28	0.70	10.6%	25.5%	6.4%	42.5%	0.06	0.13	0.03	0.22
Mato Grosso Sul	0.05	1.46	0.08	8.5%	35.0%	12.0%	55.5%	0.00	0.02	0.01	0.03
Goiás	0.07	1.57	0.12	26.5%	15.9%	10.6%	53.0%	0.02	0.01	0.01	0.04
Distrito Federal	0.00	1.29	0.00	26.5%	15.9%	10.6%	53.0%	0.00	0.00	0.00	0.00
NORTH/ NORTHEAST	**0.42**	**1.50**	**0.58**	**17.7%**	**29.1%**	**11.8%**	**58.5%**	**0.07**	**0.12**	**0.05**	**0.24**
MIDSOUTH	**0.67**	**1.33**	**0.94**	**12.9%**	**24.5%**	**7.5%**	**44.9%**	**0.09**	**0.17**	**0.05**	**0.30**
BRAZIL	**1.09**	**1.39**	**1.52**	**14.7%**	**26.3%**	**9.1%**	**50.1%**	**0.16**	**0.29**	**0.10**	**0.55**

Source: CÉLERES®.

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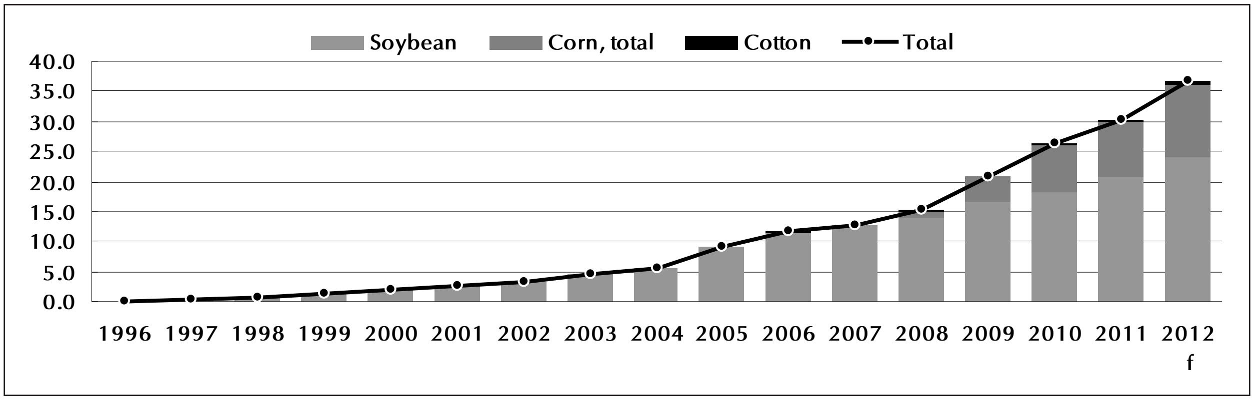
by the stacked gene technologies (IR/HT) with 5.6 million hectares. The high rate of biotech maize adoption is impressive and it is important to note that Brazil is only in its fifth sowing season and 2012 will only be the third year with an abundant supply of stacked traits for maize and cotton. Even so, it is already evident that usage of the single trait technology is decreasing fast in favor of the stacked traits. For example, stacked genes (IR/HT) increased by almost 35.8%, from 4.1 million hectares in 2011 to 5.6 million in 2012. In comparison with 2010, this technology increased 1,138.3%. Consistent with experience in other countries such as the United States and Canada, Brazilian farmers have indicated a clear preference for the stacked traits over the single traits (Figure 7).

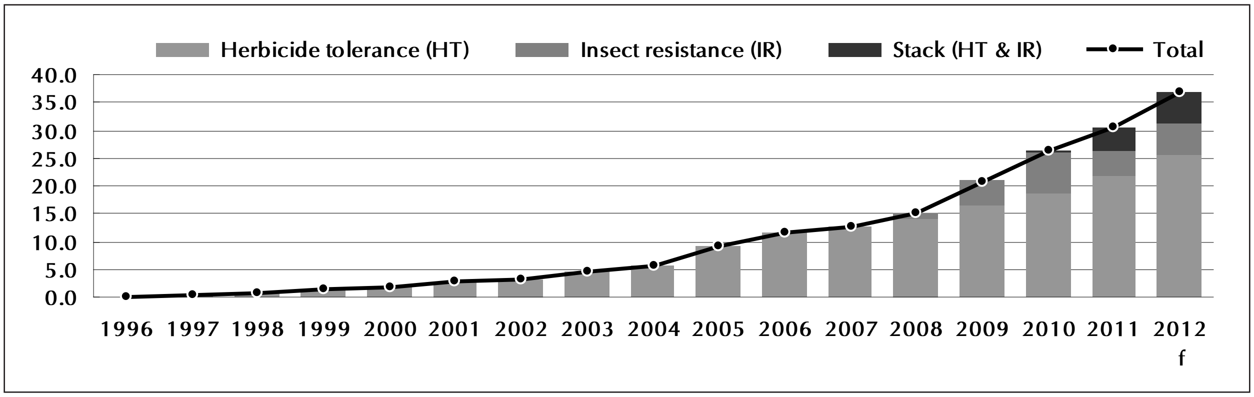
The evolution of biotech adoption rate in the three crops: cotton, corn and soybean from the year approved for planting is presented in Figure 8.

Figure 6. Biotech Crop Adoption in Brazil, by Crop. Values in Million Hectares



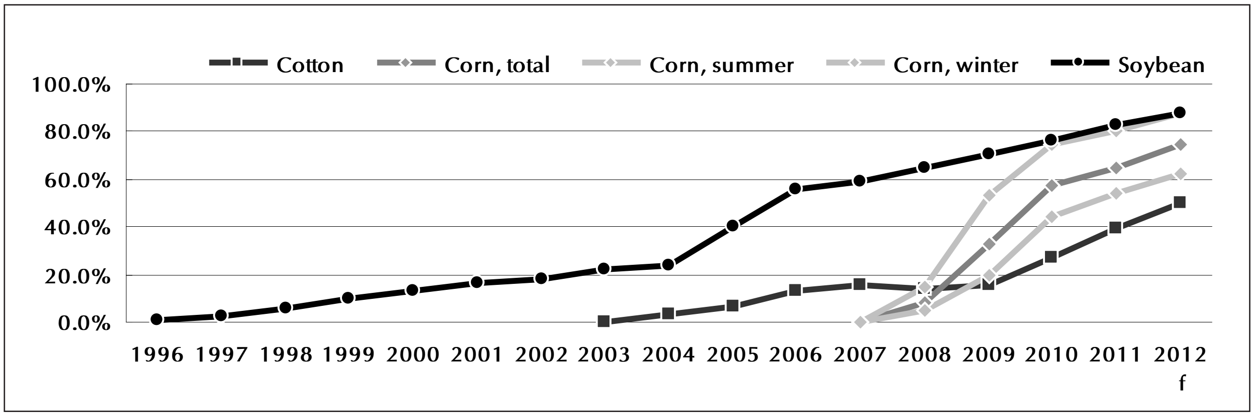
Source: CÉLERES®, 2012.

Figure 7. Biotech Crop Adoption in Brazil, by Trait. Values in Million Hectares



Source: CÉLERES®, 2012.

Figure 8. Evolution of Biotech Adoption Rate in Brazil, by Crop. As % of Total Acreage



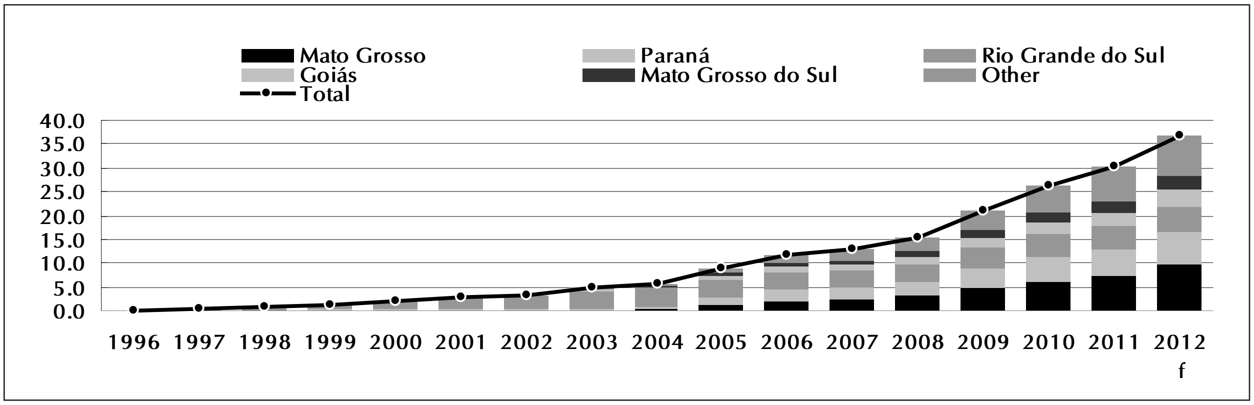
Source: CÉLERES®, 2012.

It is important to note that the stacked soybean, approved in August 2010, is approved in other countries (approval to food/feed/imports) as Korea, Taiwan, EU, USA, and other countries but not approved yet in China, the most important country to Brazilian soybean exportation. Nevertheless, selected Brazillian farmers are sowing this stacked soybean just for experiments, and the exportation will be controlled, to avoid any contamination to other traits. In as much as the technology developers were able to develop biotech varieties and hybrids adapted to the different farming regions in Brazil, a continuous migration of biotech crops was witnessed with adoption progressing from one end of the country to the other. Until 2009, Rio Grande do Sul was the leader with biotech crops, but from 2009 on, Mato Grosso is the largest state for biotech crops, with 9.9 million hectares especially with the high adoption of winter maize, followed by Paraná, with 6.6 million hectares, and Rio Grande do Sul, with 5.3 million hectares (Figure 9).

Subsequent to early judicial difficulties with biosafety in Brazil, consolidation of the federal biotech regulatory framework, and the effective functioning of CTNBio, (Brazilian National Technical Commission on Biosafety) Brazil has accelerated the approvals of biotech events and the farmers have, currently, 36 biotech approved traits in the country for farm use, five traits for soybeans, 18 for maize, nine for cotton and one for an edible virus resistant bean (Figure 10).

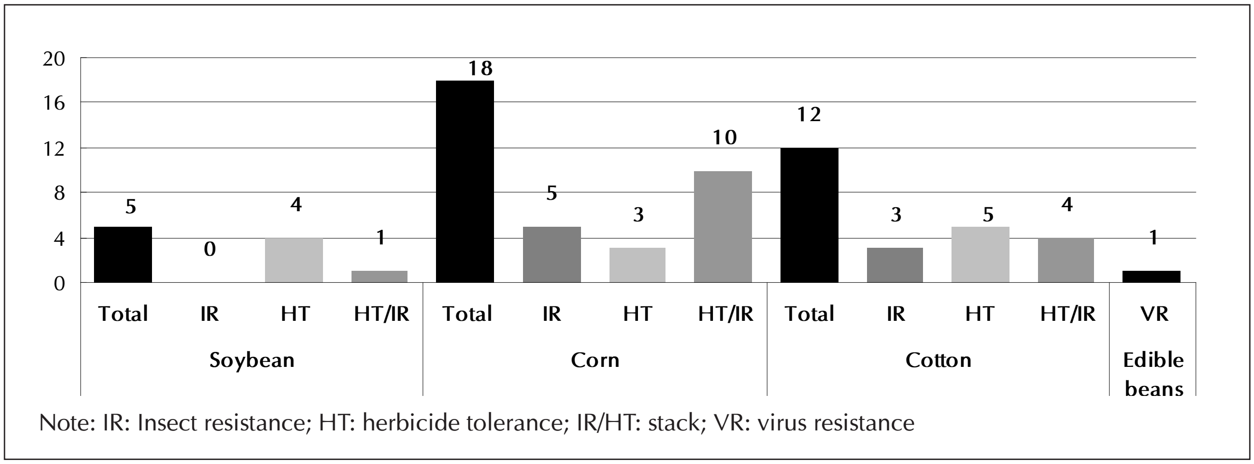
High adoption rates are an important feature of biotech crops in Brazil. Taking soybeans as an example, one of the important drivers of high adoption rates is the direct benefits realized by Brazilian farmers from using biotech soybeans rather than conventional. According to an analysis conducted since 2007/08 crop season, the production cost for one hectare of biotech soybeans was consistently less expensive than production of conventional soybeans, irrespective of region (Figure 11).

Figure 9. Biotech Crop Adoption in Brazil, by State. Values in Million Hectares



Source: CÉLERES®, 2011.

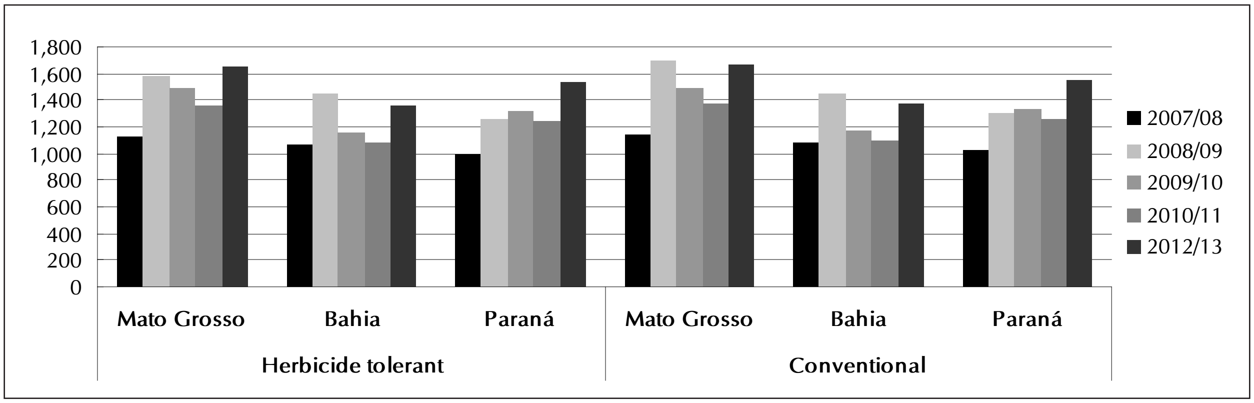
Figure 10. Number of Approved Traits in Brazil, by Crop and Traits



Note: IR: Insect resistance; HT: herbicide tolerance; IR/HT: stack; VR: virus resistance

Source: CTNBio | Elaboration: CÉLERES®

Figure 11. Evolution of Soybean Direct Production Costs in Brazil. Values in R$/hectare



Source: CÉLERES®, 2012.

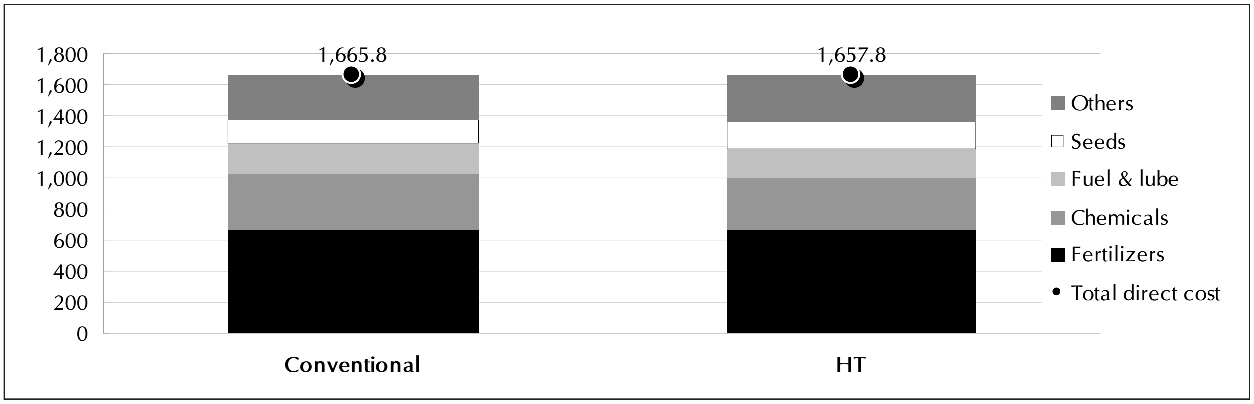
In addition to the critical importance of direct benefits, Brazilian farmers also assign high importance to the substantial indirect value related to the adoption of biotech soybeans, that impacts on efficiency gains, and the convenience and ease of weed management systems, possible only with herbicide tolerant soybeans, besides the problems with weed resistance. This problem is recurrent in Brazil, but not only with biotech soybean (as glyphosate herbicide applications), other conventional herbicides have this problem too, which could be concluded that weed resistance is a management issue, by incorrect agronomical practices.

Due to soil fertility characteristics in Brazil, fertilizer is by far the most important and costly of all inputs for soybean direct production costs. In Mato Grosso, Brazil's major soybean producer, fertilizer cost is estimated to represent 40% of all direct costs for the 2012/13 crop season. In addition to the many advantages that herbicide tolerant soybeans offer, the cost of herbicides is only 20.2% compared with 40% of fertilizers (Figure 12).

According to data from the Ministry of Agriculture (MAPA/SNRC), from 2002 to 2011, Brazil registered 728 new varieties of soybeans, out of which 497 (68%) were biotech and only 231 (32%) were conventional varieties. In the past few years, a predominance of biotech crops was clearly evident versus conventional varieties (Figure 13).

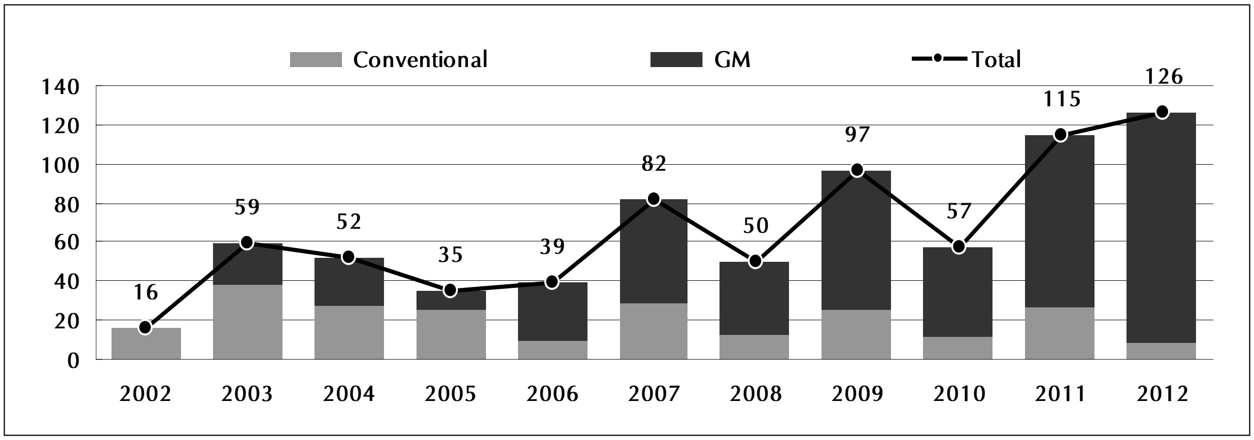
The deployment of biotech maize in Brazil is in its fifth year, following its approval by CTNBio. During this period, biotech maize developers have successfully delivered a significant number of hybrids with biotech traits. According to Brazil's Ministry of Agriculture (MAPA/SNRC), from 2002 to 2011, Brazil registered 1,037 maize hybrids, out of which 516 (~50%) are biotech hybrids – this

Figure 12. Composition of Direct Production Cost of Soybean in Brazil. Values in R$/hectare



Source: CÉLERES®, 2012.

Figure 13. Register of Soybean Varieties in Brazil



Source: MAPA/SNRC | Elaboration: CÉLERES® | Note: 2012 as of October 2nd, 2012.

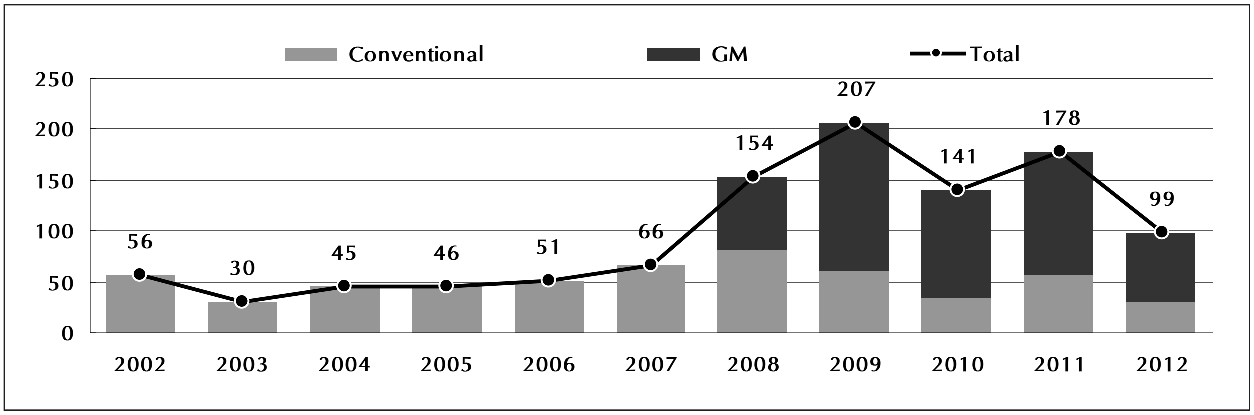
is a significant achievement given that registration of biotech events has only been in effect over the last five years (Figure 14).

A wide supply of biotech hybrids, adapted to Brazil's different regions, and combined with substantial gains in yield over the last four years, have helped convince Brazilian farmers of the multiple and significant advantages, (both direct and indirect), that biotech maize offers. Accordingly, biotech maize, has already gained the trust and confidence of farmers as a technology and hence its prevalent adoption in the different maize producing states as shown in Tables 5 to 7. It is noteworthy that there are enormous differences amongst Brazil's crop mega-environments, particularly the differences between summer and winter maize which require quite different technologies and management. The projections in Table 6 indicate that in 2012/13, the summer maize total sowed hectarage is expected to reach 8.3 million hectares (CÉLERES).

In the winter maize crop season, the adoption of biotech crops by farmers is greater and more consistent than in the case for summer maize. Practically, all of the winter maize is produced by farmers who grow soybeans in the previous summer and are therefore familiar with high-tech crop technologies, including biotech soybean. Thus, as expected biotech maize adoption rate in the winter crop season is high, reaching a projected 87.8% in the 2012/13 crop season.

In the case of cotton, the technology developers have been delivering new biotech cotton varieties to the market but at a much slower rate than the corresponding technologies for soybean and maize; the number of registered varieties is considered small by farmers and the industry. According to data published by the Ministry of Agriculture (MAPA/SNRC), Brazil registered a total (biotech and

Figure 14. Register of Maize Hybrids in Brazil

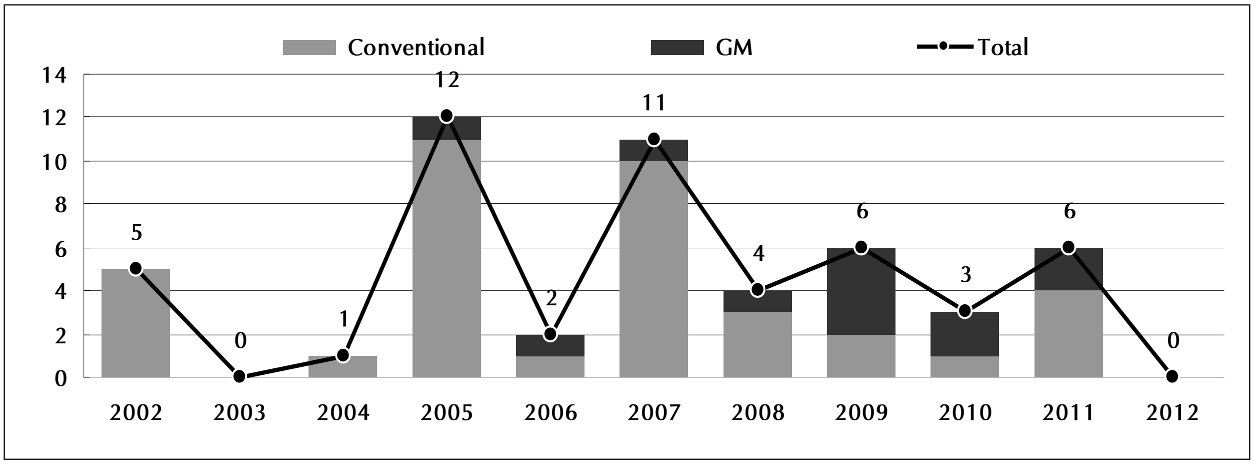


Source: MAPA/SNRC l Elaboration: CÉLERES® l Note: 2012 as of October 2nd, 2012.

conventional) of 50 new cotton cultivars since 2002. Of this number, only twelve varieties are biotech (24% of the total). The approval by CTNBio of stacked traits for cotton in 2010 is already contributing to an increase of registrations of new events in 2011 and 2012 (Figure 15). Another important aspect of biotech cotton is that a good share of the hectares planted to biotech cotton is with seeds produced by the farmers themselves; this is a disincentive to companies that need to be assured of a return on investment when developing new biotech cotton varieties. Farmer saved seeds is allowed by Brazilian legislation, but has been generating unfavorable conditions for investments in research and development of biotech cotton, which is clearly indicated by the number of cotton varieties registered in 2012 (none), neither are conventional varieties.

Even with the constraints discussed above, the recent approval of biotech cotton with stacked traits has fostered an increase in the adoption of biotech cotton in Brazil. In the 2012/13 crop season, 50.1%, or equivalent to 500,000 hectares of the national cotton area will be planted with biotech cotton. This is a 9.8% decrease, equivalent to a reduction of 100,000 hectares of biotech cotton in 2012. However, the total area of cotton in Brazil decreased, from 2011 to 2012, at -22.5%, and the adoption rate increased, from 39% to 50.1%. It is worth noting that the decision to sow cotton in Brazil can be delayed until the end of December and, in certain regions, until mid-January of 2013. Therefore, there is still the possibility for the biotech cotton hectarage to change after this Brief goes to press. Confounding all projections for cotton is the fact that the crop is subject to more volatility in prices than other crops and uncertainty about the future market in 2013. Thus, all the cotton projections in this Brief are subject to change which can impact total sowings and adoption of biotech cotton.

Figure 15. Register of Cotton Varieties in Brazil



Source: MAPA/SNRC | Elaboration: CÉLERES® | Note: 2012 as of October 2nd, 2012.

Benefits from Biotech Crops in Brazil

An annual global study of benefits from biotech crops concluded that Brazil gained US$6.6 billion during the eight year period 2003 to 2011 and US$2 billion in 2011 alone (Brooks and Barfoot 2013, Forthcoming).

Brazil is still the second country in terms of biotech crop hectarage (US is the leader) and, in 2012, it further enhanced its status by consolidating its position and decreasing the gap between it and the US, specially soybean and maize The successful development of the biotech bean confirms Brazil's internationally recognized self-sufficient capability for developing biotech crops which are important for Brazil's fast-growing domestic and export needs as well as its contribution to global food security.

Brazil, the principal exporter of biotech soybeans to China, is also developing an export market for biotech maize, and deploying biotech cotton. Brazil has also sequenced the sugarcane genome as a first step towards developing more efficient biotech sugarcane for sugar and ethanol production with insect resistance. The successful initiative to develop resistance to BGMV in Brazil can serve as a practical model for other developing countries engaged in biotech crops on how to succeed. This applies to both the scientific development of the product and importantly the timely regulatory approval of the biotech bean so that producers, consumers and the country derive maximum benefits from the investment and the technology. Brazil approved no less than a record nine biotech crops in 2009, eight in 2010, an additional six approvals in 2011, with just three in 2012 (until October), making it the country with the fastest approval rate for biotech crops globally and one of the most rigid and detailed methods for approvals, by CTNBio.

Brief Chronological Overview of crop biotech related events in Brazil in 2012 reported in ISAAA's weekly Crop Biotech Update (CBU), where original reference is provided:

1. Celeres and the Brazilian Seed and Seedling Association (ABRASEM) revealed in 2011 study that for every US$1 invested in a bag of GM seeds, Brazilian farmers earned an average of US$2.61 for corn, US$1.59 for soybean, and US$0.59 for cotton. (Crop Biotech Update, 17, April 2012).

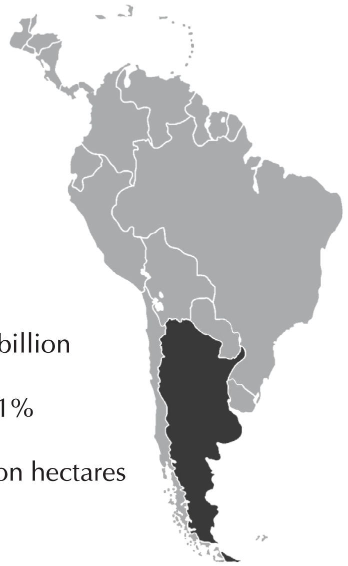
2. Brazilian scientists believe that genetically modified (GM) mosquitoes is effectively reducing populations of dengue-carrying *Aedes aegypti* mosquito, in a trial with more than 10 million male mosquitoes released in the city of Juazeiro (Crop Biotech Update, 17 April 2012). http://vaccinenewsdaily.com/medical_countermeasures/318516-genetically-modified-mosquitoes-fight-dengue-in-brazil/.

ARGENTINA

Total biotech crop hectares in Argentina in 2012 were estimated at an all time record of 23.9 million hectares. Argentina maintained its ranking as the third largest producer of biotech crops in the world in 2012 occupying 14% of global hectarage. In 2012, Argentina was expected to plant a total hectarage of 23.9 million hectares of biotech soybean, maize and cotton, up by 0.2 million hectares from 23.7 million hectares in 2011. Of the 23.9 million hectares of biotech crops in 2012, 20.2 million hectares were biotech soybean, 3.3 million hectares were biotech maize and 0.4 million hectares were biotech cotton. Biotech soybean was up by 1.1 million hectares due to its substitution for biotech maize plantings which were 3.3 million hectares in 2012 compared with 3.9 million hectares in 2011, a 15% decrease. Biotech cotton decreased in line with a decrease of total cotton hectarage globally and in Argentina, this resulted in a decrease from 675,000 hectares in 2011 to 350,000 hectares in 2012; farmers substituted soybean for cotton because of the higher prices and margins from biotech soybean. Positive trade discussions between Argentina and China to export Argentinean biotech maize to China has provided a great incentive and boost for biotech maize in the longer term in Argentina. In summary, in 2012, Argentina has

achieved a marked improvement in its promotion of biotech crops and has pursued their timely regulation aggressively. CONABIA now has an impressive stable of products for evaluation from both the public and private sector. According to Trigo (2011), benefits from biotech crops alone for the first 15 years (1996-2010) were estimated at US$72.36 billion and the creation of 1.82 million jobs.

ARGENTINA



Population: 39.9 million

GDP: US$328 billion

GDP per Capita: US$8,240

Agriculture as % GDP: 10%

Agricultural GDP: US$32.8 billion

% employed in agriculture: 1%

Arable Land (AL): 33.2 million hectares

Ratio of AL/Population*: 3.3

Major crops:
- Soybean
- Maize
- Sugarcane
- Sunflower seed
- Wheat

Commercialized Biotech Crops:
- HT Soybean
- Bt/HT/Bt-HT Cotton
- Bt/HT/Bt-HTMaize

Total area under biotech crops and (%) increase in 2012:
23.9 Million Hectares (+1%)

Farm income gain from biotech, 1996-2011: US$14 billion

*Ratio: % global arable land / % global population

Total biotech crop hectares in Argentina in 2012 was estimated at an all time record of 23.9 million hectares. Argentina is one of the six "founder biotech crop countries", having commercialized RR®soybean and Bt cotton in 1996, the first year of global commercialization of biotech crops. After retaining the second ranking position in the world for biotech crops area for 13 years, Argentina was narrowly displaced from being the second largest producer of biotech crops in the world in 2009, by Brazil. The 27 biotech crop products approved for commercial planting in Argentina and for import as food and feed products are listed in Table 9 including the designation of the event and the year of approval. It is noteworthy that a significant number of 5 new biotech crop events were approved in 2012.

In 2012, the year-over-year increase, compared with 2011, was 0.2 million hectares with an annual growth rate of 1% over 2011. Of the 23.9 million hectares of biotech crops in Argentina, 20.2 million hectares were expected to be planted to biotech soybean, up by 1.1 million hectares over 2011. The 20.2 million hectares of biotech soybean is equivalent to 100% of the planting of 20.2 million hectares of the national soybean crop. The increase in soybean plantings in 2012 over 2011 is mainly due to farmers planting significantly more soybean in 2012 than 2011, and less maize and cotton.

Table 9. Commercial Approvals for Planting, Food and Feed in Argentina, 1996 to 2012

Crop	Trait	Event	Year
Soybean	Herbicide tolerance	40-3-2	1996
Maize	Insect resistance	176	1998
Maize	Herbicide tolerance	T25	1998
Cotton	Insect resistance	MON531	1998
Maize	Insect resistance	MON810	1998
Cotton	Herbicide tolerance	MON 1445	2001
Maize	Insect resistance	Bt11	2001
Maize	Herbicide tolerance	NK603	2004
Maize	Herbicide tolerance x Insect resistance	TC1507	2005
Maize	Herbicide tolerance	GA21	2005
Maize	Herbicide tolerance x Insect resistance	NK603 x MON810	2007
Maize	Herbicide tolerance x Insect resistance	TC 1507 x NK603	2008
Cotton	Herbicide tolerance x Insect resistance	MON1445 x MON531	2009
Maize	Herbicide tolerance x Insect resistance	GA21 x Bt11	2009
Maize	Insect resistance	MON89034	2010
Maize	Herbicide tolerance x Insect resistance	MON88017	2010
Maize	Herbicide tolerance x Insect resistance	MON89034 x MON88017	2010
Maize	Insect resistance	MIR 162	2011
Soybean	Herbicide tolerance	A2704-12	2011
Soybean	Herbicide tolerance	A5547-127	2011
Maize	Herbicide tolerance x Insect resistance	Bt11 x GA21 x MIR162	2011
Maize	Herbicide tolerance	DP-098140-6	2011
Maize	Insect resistance	MIR604	2012
Maize	Herbicide tolerance x Insect resistance	Bt11 x MIR162 x MIR604 x GA21	2012
Maize	Herbicide tolerance x Insect resistance	MON89034 x TC1507 x NK603	2012
Maize	Herbicide tolerance x Insect resistance	MON89034 x NK603	2012
Soybean	Herbicide tolerance x Insect resistance	MON89788 x MON87701	2012

Source: ArgenBio, 2012 (G. Levitus, Personal Communication)

The total maize hectarage in 2012 was ~3.9 million hectares, of which about 3.3 million hectares were biotech composed of 3.1 million hectares planted to the stacked product Bt/HT, 25,000 hectares to the single Bt product, and 200,000 hectares to herbicide tolerant maize. Thus, the stacked gene Bt/HT maize product occupied about ~94% of the biotech maize and is expected to retain this premier position in the future. Successful talks between Argentina and China to export the first Argentinean biotech maize to China in 2011/12 provided a great incentive and boost for the long term view on biotech maize in Argentina.

Argentina reported a total planted area of 354,000 hectares of cotton for 2012, down from 690,000 hectares in 2011. Of the 354,000 hectares of total cotton plantings in 2012, 350,000 hectares or 99% were biotech, comprising 260,000 hectares of Bt/HT stacked product, about 75,000 hectares of herbicide tolerant (HT), and 15,000 hectares Bt and the balance of 4,000 hectares were conventional. Consistent with a global trend, farmers in Argentina substituted soybeans for cotton because of higher prices and margins for soybean. The general increase in biotech cotton up to 2011 was related to various factors including the availability of better adapted biotech varieties, improved returns and more awareness by farmers of the benefits associated with the technology, and improved reporting. It is noteworthy that farmer-saved seed, which is prevalent in Argentina, can lead to problems with Bt cotton if the purity drops to a point where larvae can establish on non-Bt cotton plants and start an infestation which can compromise insect resistant management strategies. There has been a shift towards more cotton grown on larger farms due to the damage caused by boll weevil which is more easily controlled by larger farmers than smaller farmers.

There were several important developments in Argentina in 2012. The following is a summary of a comprehensive recent overview (GAIN Report for Argentina, 18 July 2012).

- On 16 March 2012, the Secretary of Agriculture, Lorenzo Basso announced the implementation of a new regulatory framework for agricultural biotechnology. The goal is to reduce approval time of events from 42 months to 24 months and progress is being made. According to CONABIA (National Advisory Committee on Ag Biotech) the flow of applications tripled from 1999, so, the change was urgently needed. In 2012, Argentina approved Syngenta's quadruple event in maize before Brazil which it has trailed in the past.

- Argentinian scientists have developed a drought tolerant biotech sugarcane and are exploring cooperation to further develop this product with Brazil which is also working on drought tolerant sugarcane. The product from this joint program could be ready by 2013 and approved for production by 2017. Such a product would allow Argentina to increase sugarcane hectarage from the current 350,000 hectares to 5 million hectares in the future. Most of the extra production of sugarcane would be for ethanol production.

- CONABIA is currently evaluating two other sugarcane products – RR®sugarcane and Bt sugarcane – the RR®sugarcane could be approved for commercialization as early as 2014, and if so would be the first biotech sugarcane to be commercialized globally.

- In another initiative, Argentinian scientists have also transferred a drought tolerant gene from sunflower to maize, soybean and wheat. BioCeres, an Argentinian company, has been granted a license for this gene and has a joint venture named Verdeca, with Arcadia Biosciences from the US. Field trials with the new seeds have increased yield by 15% or more and Verdeca has indicated that the drought tolerant seeds could be in the market as early as 2015/16.

- Finally, CONABIA is currently evaluating biotech potatoes resistant to viruses Y and PLRV (which cause significant losses in Argentina) as well as herbicide tolerance. This product could be approved for commercial production as early as 2013.

- Industry investments in Argentina in 2012 have increased significantly with Monsanto investing US$355 million in a new maize production facility and Syngenta with US$175 million in a seed production facility.

- A private agreement between farmers and Monsanto came into effect to deal with payment for the use of RR2Y soybean and RR2YBt (stacked). This agreement involves 8,000 farmers, representing 11 million hectares of soybean, which is equivalent to 60% of the total area of soybean in Argentina.

- In December 2011, an Argentine Chamber of Biotechnology was created for both public and private sector participants. As its first initiative, the Chamber has commissioned a study to “map” various aspects of agriculture biotechnology in Argentina. This coincides with a Government program to increase public awareness of ag-biotechnology and has made biotechnology a mandatory subject in school – 11,000 teachers have already received copies of the children’s text book “Por Que Biotecnologia” or “Why biotechnology”.

In summary, in 2012, Argentina has achieved a marked improvement in its promotion of biotech crops and pursued their timely regulation aggressively; CONABIA now has an impressive stable of products for evaluation from both the public and private sector.

Benefits from Biotech Crops in Argentina

Farmers in Argentina have been benefiting immensely from biotech crops for the past fifteen years. A detailed study by Eduardo Trigo was recently released that provide information on the economic impact in Argentina (Trigo, 2011). The press release of that study published in 28 November 2011 is reproduced with permission from the author.

Economic Impact after 15 years of GM crops in Argentina

Agricultural biotechnology afforded the country over 70 billion dollars

Since 1996, when glyphosate-tolerant soybean was introduced, Argentina has been one of the leading countries in the utilization of genetically modified (GM) crops, reaching 22.9 million hectares planted in the last growing season. The adoption process of these technologies has been fast and steady, with an unprecedented dynamics which allowed that GM varieties currently represent practically all the planted area with soybean, 86% in the case of maize and 99% for cotton.

According to a recent study carried out by Dr. Eduardo Trigo for ArgenBio the Argentine Council for Information and Development of Biotechnology – the gross benefit generated by this adoption process for the period 1996-2010 reaches US$72,363 million. These benefits were estimated using SIGMA, a mathematical model developed by INTA (National Institute for Agricultural Technology) that uses data from the Technological Profile of Argentina's Agricultural Sector (INTA), with additional information provided by the Ministry of Agriculture, Livestock and Fisheries, ArgenBio, INDEC (National Institute of Statistics and Census) and FAO.

Economic benefits, by crop

- In the case of glyphosate-tolerant soybean, the benefits mounted to 65,153 million US dollars, 3,231 million attributable to a reduction in production costs (mainly due to less tillage and reduced applications of selective herbicides required by conventional varieties) and 61,917 million due to the expansion of the planted area. Regarding the distribution of the total benefits, 72.3% went to farmers, 21.3% to the National Government – collected through export tax and other taxes – and 6.5% to technology providers (seeds and herbicides) (Table 10).
- In the case of maize, insect resistance and herbicide tolerance technologies gave benefits for a total amount of 5,375 million US dollars, distributed as follows: 68.2% to growers, 11.4% to the National Government and 20.4% to technology providers (mainly seeds).

Table 10. Economic Benefits of Biotech Crops (Million US$) and Percentage Distribution

Crop and Trait	Total Benefits	Amount (Percentage) of Benefits Accrued to		
		Farmers	National Government	Technology Developers
HT Soybean	65,153	47,105.0 (72.3)	13,877.6 (21.3)	4,169.8 (6.4)
Bt/HT Corn	5,375	3,665.8 (68.2)	612.8 (11.4)	1,096.5 (20.4)
Bt/HT Cotton	1,834	1,760.6 (96.0)	0	73.4 (4.0)

Source: Trigo, 2011.

- Finally, in the case of insect-resistant and herbicide-tolerant cotton, total benefits reached 1,834 million US dollars that went mainly to farmers (96%), with 4% going to technology providers (seeds and herbicides).

More benefits

In addition, and given the importance of Argentine soybean production worldwide, this study estimated the global impact in terms of savings that the adoption of such technology by Argentine farmers has had on consumer expenditure (by reducing the global price). The total cumulative figure for 1996-2011 was estimated at about US$89 billion. In terms of prices, figures show that if this adoption process had not occurred, the international price of soybean in 2011 would have been 14% higher than it actually was.

On the socio-economic side, the impact that GM technologies have had on job creation was assessed. Based on these estimates, the generation of 1.82 million jobs by the Argentine economy along these 15 years could be attributed to the use of GM technologies.

Dr. Eduardo Trigo's work also analyzed some environmental impacts related to GM crops, with special emphasis on the particular synergy between the expansion of these crops and no-till farming practices, and its positive impact on soil structure and the efficient use of energy.

Future benefits.

Looking ahead and using the same methodology applied for the retrospective analysis, the study estimates the potential benefits that could be generated by two different types of GM crops: an herbicide tolerant and insect resistant soybean, and a drought-resistant wheat, under three different price and adoption scenarios. Results show that, if these technologies were available as from the next growing season, accumulated benefits in the 10 following years could be US$9,131 million to US$26,073 million for soybean and US$526 million to US$1,923 million for wheat, according to different scenarios.

Argentina must remain a leader so as not to miss opportunities

"One of the characteristics of the adoption process of GM crops in Argentina is the fact that our country has been an early adopter worldwide," stated Eduardo Trigo, who explained that ***"the introduction of herbicide-tolerant soybean in our agriculture was made available to farmers practically at the same time as in the American market for which it was originally designed. In this 15 years, this has given us an important amount of economic and other benefits as the study shows."***

"The advantages of being at the front of innovative processes are very clear and, as a consequence, so are the risks or opportunity costs that the country would face if it followed a less dynamic technology adoption process than in the past. Keeping the "early adopter" profile is a strategic issue that should include key topics like regulatory processes, the promotion of investments for the sector and the redistribution of benefits into areas like innovation, economic growth and social welfare," said Eduardo Trigo, the author of the Report.

The key to success.

"The biotechnology adoption process in Argentine agriculture has been undoubtedly very successful," said Gabriela Levitus, Executive Director of ArgenBio. ***"Not only because our products have been competitive and the international prices have been good, but also because when this technology was made available, the country was ready to adopt it. There were world class breeder, trained and innovative farmers and there was the political will that resulted in the creation of a pioneer regulatory system, which guaranteed the safe adoption of GM crops in our country from the start. This political will, very clear 15 years ago but quite changeable along the last years, is today strong again; this fact is clearly shown through the new approvals and the recent revision of the regulatory processes boosted by the Ministry of Agriculture, Livestock and Fisheries. Contrary to other times, agricultural biotechnology is now a state policy,"*** concluded Levitus.

In the most recent global study on the benefits from biotech crops (Brookes and Barfoot, 2013, Forthcoming) estimates that Argentina has enhanced farm income from biotech crops by **US$14 billion in the first sixteen years** of commercialization of biotech crops 1996 to 2011, and the benefits **for 2011 alone were estimated at US$1.9 billion.**

Brief Chronological Overview of crop biotech related events in Argentina in 2012 reported in ISAAA's weekly Crop Biotech Update (CBU), where original reference is provided:

1. The Secretary of Agriculture of Argentina has approved Syngenta's genetically modified corn MIR604 and quadruple corn stack Bt11 x MIR162 x GA21x MIR604 also called Agrisure Viptera®4 for cultivation (Crop Biotech Update, 23 March 2012).
2. POWERCORE Corn™, Dow Agro Sciences' first product with five genes stacked that provides control against fall armyworm, sugarcane borer, corn earworm, corn stalk borer, black cutworm and tolerance to glyphosate and glufosinate has been approved in Argentina and Brazil (Crop Biotech Update, 25 May 2012).

Farmer Experience

Martin Arechavaleta is a soybean grower and a third generation farmer in Victoria, Province of Entre Rios, Argentina. He told of his old farm practices when products were expensive and difficult to apply. ***"We had to live with many problems. Production was half of what we have now,"*** he says.

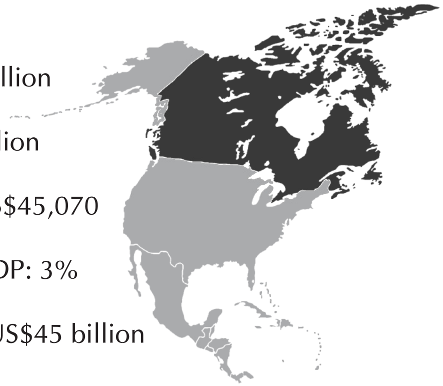
He first incorporated biotechnology into his farm more than 10 years ago when he started planting glyphosate-resistant soybean. ***"We have seen many advantages over the years with the new products. Before, it was a lot of mechanical work to get rid of weeds. Now, the producer is more free, there is more production and less cost"*** (Arechavaleta, 2010).

Mario Alberto Sanchez, started his family farm enterprise of around 30 hectares with soybeans, corn, sorghum, and sunflowers. This increased to 3,300 hectares over the past 22 years due to his sustainable cropping practices as well as his adoption of biotech seed and crop protection practices. He has grown glyphosate-tolerant corn and soybeans which led to increased profits and reduced costs. ***"We started using the product because of the quality of the seeds. We began testing and realized that besides the quality improvement, there was an increase in performance,"*** he says, adding that fewer crop protection applications and working in a preventative way is a real plus. ***"With this product we're more relaxed. The leftover time can be devoted to family, or in our case, we can rent or buy more land and then we can advance"*** (Sanchez, 2010).

CANADA

In 2012, Canada is in the fourth place in world ranking of biotech crops. Growth in biotech crop hectarage continued in Canada in 2012 to reach a record 11.6 million hectares for a net gain of 1.2 million hectares, equivalent to a 12% year-over-year growth for the four biotech crops of canola, maize, soybean and sugarbeet, with most of the growth due to higher plantings of canola at a record 97.5% adoption. Biotech hectares for maize and soybean were also significantly higher due to larger plantings of the two crops; biotech sugarbeet was the same as 2011 at ~15,000 hectares, similar to 2011. Canada is estimated to have enhanced farm income from biotech canola, maize and soybean by US$4 billion in the period 1996 to 2011 and the benefits for 2011 alone is estimated at US$611 million.

CANADA



Population: 33.2 million

GDP: US$1,501 billion

GDP per Capita: US$45,070

Agriculture as % GDP: 3%

Agricultural GDP: US$45 billion

% employed in agriculture: 3%

Arable Land (AL): 49.9 million hectares

Ratio of AL/Population*: 6.0

Major crops:
- Wheat
- Barley
- Maize
- Rapeseed
- Potato

Commercialized Biotech Crops:
- HT Canola
- HT Soybean
- HT/Bt/HT-Bt Maize
- HT Sugarbeet

Total area under biotech crops and (%) increase in 2012:
11.6 Million Hectares (+12%)

Farm income gain from biotech, 1996-2011: US$4 billion

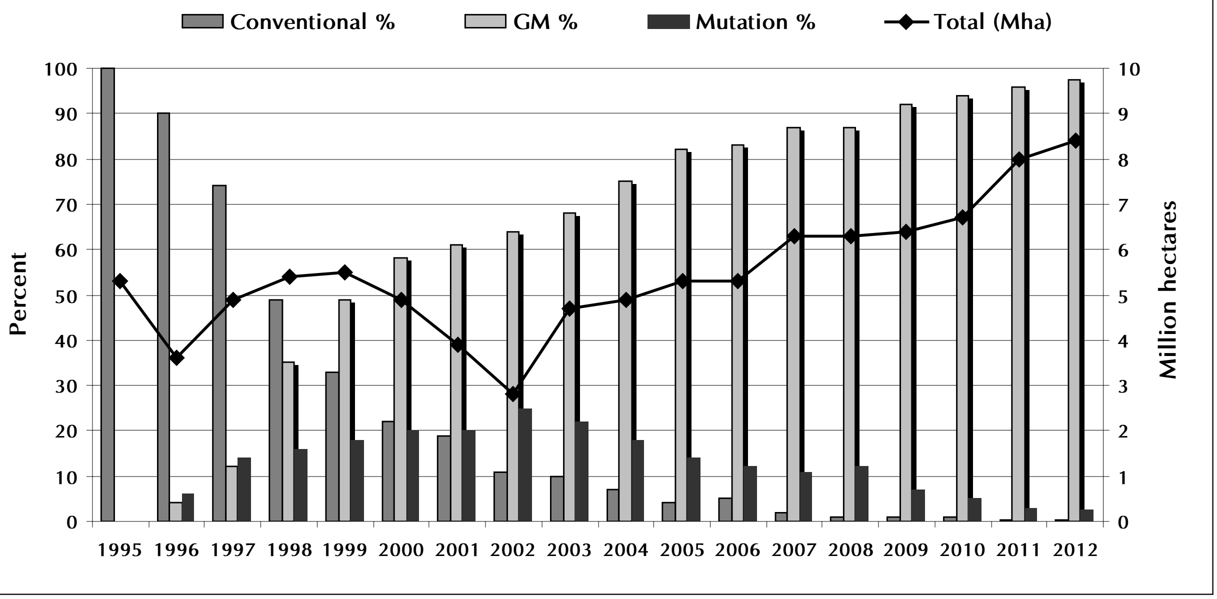
*Ratio: % global arable land / % global population

Canada is a member of the group of six “founder biotech crop countries”, having commercialized herbicide tolerant canola in 1996, the first year of commercialization of biotech crops. In 2012, Canada retained its fourth place in world ranking of biotech crops. Growth in biotech crop area continued in Canada in 2012 with a net gain of approximately 1.2 million hectares, equivalent to an 12% year-over-year growth, with a total biotech crop area of 11.6 million hectares for the four biotech crops of canola, maize, soybean and sugarbeet, with most, but not all, of the growth due to higher plantings of canola with a record 97.5% adoption, 1.5% higher than last year, with significant growth in both soybean and maize due to larger plantings. The largest biotech crop area by far, is herbicide tolerant canola, most of which is grown in the west where adoption rates are very high.

The total land area planted to canola in Canada in 2012 was a record 8.62 million hectares, up 8% from the 8.0 million hectares in 2011. In 2012, the national adoption rate for biotech canola was a record 97.5%, 1.5% higher than last year, compared with 96% in 2011, 94% in 2010, 93% in 2009, 86% in both 2008 and 2007, 84% in 2006 and 82% in 2005 (Figure 16). In 2012, biotech herbicide tolerant canola was grown on approximately 8.40 million hectares, 9% more than the 7.7 million hectares of biotech canola grown in 2011, 6.3 million hectares in 2010, 6.0 million hectares in 2009, 5.5 million hectares in 2008, 5.1 million hectares in 2007 and 4.5 million hectares in 2006. Thus, in Canada there has been an impressive, steady and significant increase both in the total land area planted to canola in the absolute hectares and in the percentage planted to herbicide tolerant biotech canola, which has now reached a record high national adoption rate of 97.5%; mutation based canola was estimated at 2.48% of total hectarage and conventional at 0.2% (Personal Communication Canola Council of Canada, 2012).

In Ontario and Quebec, the major provinces for maize and soybean hectarage, the total plantings of maize for all purposes in 2012 were 1.7 million hectares and 1.7 million hectares for soybean, with both up significantly from last year. The 2012 total plantings of sugarbeet were the same as 2011 with 18 thousand hectares of biotech herbicide tolerant sugarbeet at 96% adoption, the same

Figure 16. Percentage of Conventional, Biotech and Mutation-based Herbicide Tolerant (HT) Canola Planted in Canada, 1995 to 2012 (Million Hectares)



Source: Compiled by Clive James, 2012.

as last year. In 2012, the area of biotech maize, was 1.6 million hectares, up significantly from last year's 1.3. Canada is one of only nine countries (the others are the USA, Brazil, Argentina, the Philippines, South Africa, Uruguay, Honduras and Chile) which grow maize with double stacked traits for herbicide tolerance and Bt for insect resistance. Similarly, except for the USA, Canada is the only country to grow a triple stack with one gene for European corn borer, a second for root worm control and a third for herbicide tolerance. Of the biotech maize in Canada in 2012, only 21% contained a single gene, compared with 25% in 2011, and 68% in 2008. In 2012, 79% contained 2 or 3 stacked genes compared with 76% in 2011, 70% in 2010 and 54% in 2009. This growth in double and triple stacked genes versus single genes is typical of the shift in favor of stacked genes compared with single genes that has occurred in all seven countries that deploy stacked genes in maize. In 2012, of the total soybean hectarage of 1.7 million hectares, the biotech soybean hectarage was 1.6 million hectares.

Biotech RR®sugarbeet were planted in Canada in 2012, for the fifth time after being launched in 2008. It is estimated that in 2012, 96% (same as 2010) of the sugarbeet in Canada, equivalent to approximately 14,000 hectares were RR®sugarbeet. This was the fifth year of planting in Ontario in Eastern Canada, (with the beets transported and processed in the USA) and the fourth year of production in Western Canada where they were also processed.

It is estimated that approximately 2% of the Canada canola production will be used for biofuel by 2012. Canada is a major producer of wheat and several of the current principal wheat varieties have been developed through mutagenesis – there is increased interest in biotech wheat. Maize with higher levels of lysine is undergoing field tests. The RR®alfalfa from the USA has also been approved for import to Canada.

Benefits from Biotech Crops in Canada

Canada is estimated to have enhanced farm income from biotech canola, maize and soybean by US$4 billion in the period 1996 to 2011 and the benefits for 2011 alone is estimated at US$611 million (Brookes and Barfoot, 2013, Forthcoming).

The detailed benefit study of biotech canola, conducted by the Canola Council of Canada in 2007 is summarized below. Biotech canola was by far the largest hectarage of biotech crops in Canada in 2007 representing approximately 75% of the total biotech crop area of 7 million hectares. The detailed study (Canola Council of Canada, 2007) involved 650 growers; 325 growing conventional and 325 growing herbicide tolerant biotech canola. The study covered the period 1997 to 2000 and the major benefits were the following:

- More cost effective weed management was the most important advantage attributed by farmers to herbicide tolerant canola with herbicide cost 40% lower for biotech canola (saving of 1,500 MT of herbicide in 2000) compared with conventional canola.
- A 10% yield advantage for biotech canola over conventional and the dockage was only 3.87% for biotech canola compared with 5.14% for conventional.
- Less tillage and summer fallow required for biotech canola which required less labor and tractor fuel (saving of 31.2 million liters in 2000 alone) and facilitated conservation of soil structure and moisture and easy "over the top" spraying for weeds after crop establishment.
- Increased grower revenue of US$14.36 per hectare and a profit of US$26.23 per hectare for biotech canola over conventional.
- At a national level the direct value to growers from 1997 to 2000 was in the range of US$144 to US$249 million.
- The indirect value to industry of biotech canola was up to US$215 million for the same period 1997 to 2000.
- The total direct and indirect value to industry and growers for the period 1997 to 2000 was US$464 million.
- Extrapolating from the period 1997 to 2000 when 8,090,000 hectares of biotech canola were grown for a gain of US$464 million and the additional 19,809,000 hectares grown during the period 2001 to 2007, the total direct and indirect value to industry and growers for the period 1997 to 2007 is of the order of US$1.6 billion.

A more recent analysis reported in 2010, on 2005 to 2007, data by Smyth et al. (2010) concluded that herbicide tolerant canola in western Canada had generated between Ca$1.063 billion and Ca$1.192 billion in direct and indirect/spill-over benefits for producers during the three year period 2005 to 2007 with an average annual economic benefit of almost Ca$400 million (Ca$397) (Table 11). The authors concluded that the economic benefits were partly attributed to lower production costs and to improved weed control. The findings of the survey were similar to earlier studies (Canola Council of Canada, 2007). The 2010 Report (Smyth et al. 2001) ***"refutes the claims and accusations made by critics of agricultural biotechnology that genetically modified crops do not benefit farmers and are harmful to the environment"*** – on the contrary it reports that the economic and environmental benefits are numerous and substantial.

Table 11. Direct and Spill-over Benefits of HT Canola (Ca$M)

Year	Million Acres	Direct	Spill-over		Reduced tillage	Cost of volunteer control	Total Benefits	
			Low	High			Low	High
2005	12.6	141	63	103	153	14	343	383
2006	12.8	143	64	105	153	14	346	387
2007	14.8	165	73	121	153	17	374	422
Average	13.4	150	67	110	153	15	354	397
Total							**$1,063**	**$1,192**

Source: Smyth et al. 2010.

Farmer Experience

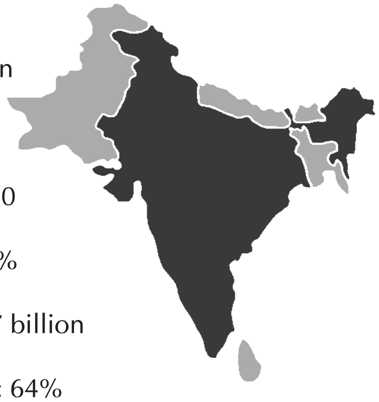
Brian Chorney operates the family-owned John Chorney Farms in East Selkirk, Manitoba, Canada. The farm which was established by his grandfather was used to having a summer fallow to control weeds. Today, Chorney has access to a wide range of tools to improve crop productivity and enable sustainable farming including biotech products such as herbicide-tolerant soybeans and canola to control difficult weeds. ***"Biotechnology adds tools to our toolbox as farmers. We can look at different methods of controlling weeds,"*** says Chorney, ***"Prior to crop protection products and biotechnology, the only method of controlling weeds was cultivation. Now I don't have planned summer fallow and I can clean up fields by growing different crops."*** With the wide variety of crops to choose from Chorney said, ***"Biotech crops have given us the opportunity to look at our crop rotation on a holistic approach. If you look at a canola, winter wheat, soybean, spring wheat type rotation, it is a diverse approach that is sustainable long-term for our farm viability"*** (Chorney, 2010).

Jim and Denise Timmings operate a 4,000 acre Timstar Farms in Rockwood, Southern Ontario, Canada. The 40-year family farm business was made profitable and sustainable in the last decade due to the family's hard work and their adoption of agricultural innovations such as plant biotechnology and crop protection products. ***"Growing the crops we grow is difficult, if not impossible, without crop protection products,"*** says Timmings. ***"We have to control the weeds, we have to maintain the yields in order to be profitable and biotech crops have allowed us to do some different things to be sustainable"*** (Timmings, 2010).

INDIA

2012 was the eleventh successful year of the commercialization of Bt cotton in India. In 2012, despite opposition by NGOs, 200,000 more farmers than 2011, totaling 7.2 million, planted Bt cotton because a decade of farmer experience with Bt cotton has confirmed that it consistently delivers significant and multiple benefits to cotton farmers in India. Bt cotton technology has effectively controlled *Helicoverpa armigera* infestations that caused devastation to the cotton crop in the past. For the 11th successive year, Bt cotton has suppressed the infestations of bollworm – the last devastating infestation occurred in 1997, prior to the introduction of Bt cotton in 2002. In 2012, India posted a modest increase of 200,000 hectares over the 10.6 million hectares of Bt cotton in 2011, to total 10.8 million hectares – equivalent to a 93% adoption rate of the total 11.6 million hectares cotton planted in India in 2012. Thus, in 2012, the near optimal 93% adoption for Bt cotton increased by 5% from 88% in 2011. Notably, this modest increase of 5% in Bt cotton hectarage is remarkable in the eleventh year of commercialization particularly when it occurred at a time when total hectarage of cotton in India actually declined by 0.5 million hectares from 12.1 million hectares in 2011 to 11.6 million hectares in 2012. The increase in adoption rate of 5% (in sharp contrast to the substantial decrease in total cotton hectarage) reflects the trust and confidence of 7.2 million small farmers in Bt cotton in India. The decrease in total cotton area was due to the late arrival of an erratic monsoon in the 2012 *Kharif* season that resulted in a drought-like-situation in the major cotton growing states of Gujarat, Maharashtra, Karnataka and the Northern cotton growing region. Again in 2012, the principal beneficiaries of Bt cotton were

INDIA



Population: 1,186.2 million

GDP: US$1,159 billion

GDP per Capita: US$ 1,020

Agriculture as % GDP: 17%

Agricultural GDP: US$197 billion

% employed in agriculture: 64%

Arable Land (AL): 177.5 million hectares

Ratio of AL/Population*: 0.60

Major crops:
- Sugarcane
- Vegetables, fresh
- Rice
- Potato
- Wheat
- Cotton

Commercialized Biotech Crop: Bt Cotton

Total area under biotech crops and (%) increase in 2012:
10.8 Million Hectares (+2%)

Farm income gain from biotech, 2002-2011: US$12.6 billion

*Ratio: % global arable land / % global population the 7.2 million small, resource-poor cotton farmers – the masters of risk aversion – growing on average ~1.5 hectares of Bt cotton. The 93% adoption rate for Bt cotton in India in 2012 is the highest ever recorded in the country and compares favorably with 99.5% adoption for biotech cotton in Australia, 94% in the USA and 80% in China.

2012 was "a-decade-plus one" experience with biotech cotton in India that allowed 7.2 million small farmers to transform the cotton crop into the most productive and profitable crop in the country. Historically, the increase from 50,000 hectares of Bt cotton in 2002, (when Bt cotton was first commercialized) to 10.8 million hectares in 2012 represents an unprecedented 216-fold increase in eleven years. India enhanced farm income from Bt cotton by US$12.6 billion in the ten year period 2002 to 2011 and US$3.2 billion in 2011 alone compared with US$2.5 billion in 2010. Bt cotton has revolutionized cotton production in India by increasing yield, decreasing insecticide applications, and through welfare benefits, contributed to the alleviation of poverty of 7.2 million small resource-poor farmers and their families in 2012 alone; thus, the number of Bt cotton poor beneficiaries totaled ~30 million poor people, based on a conservative estimate of an average of 4 members per farming family. Accumulatively ~39 million small farmers in India have benefited from planting Bt cotton repeatedly year-after-year during the eleven year period 2002 and 2012. Thus, India has successfully harnessed the significant benefits that Bt cotton offers (from both single and double Bt genes) and the future holds enormous potential as the next generation of biotech cotton offers India a range of beneficial new traits including the stacked Bt/HT cotton, drought and salinity tolerance, disease resistance, sucking pest resistance, leaf curl virus resistance and other traits related to cotton fiber quality.

The future of cotton in India looks promising. Lifting of export restrictions for cotton in 2012 would allow seed producers and farmers to plan ahead for cotton production. The aim is to achieve a new record of 40 million bales for 2015; this will exceed the predicted requirement of 41.3 million bales by 2019/20. The first decade of Bt cotton 2002 to 2011 produced impressive "mountains" of raw cotton, which looked like "white gold" increasing national cotton production from 13.6 million bales in 2002 to 35.3 million bales in 2011 – a substantial 160% increase in a short span of ten years. The first year, 2012, of the second decade of Bt cotton from 2012 to 2021 has consolidated production gains and preparatory work on a range of "new" biotech traits to complement the insect resistant Bt trait that has already become an integral part of the commercial cotton germplasm in India. The "new traits" that will be made available to small farmers in the future include herbicide tolerance, drought tolerance and resistance to lygus bugs, coupled with improved insect resistance. Timely approval and deployment of these new biotech cotton traits is of paramount importance; the new

traits will provide the technological continuity necessary for developing increasingly improved biotech cotton and generate the momentum for growth that will ensure prosperity for small cotton farmers in India with the expectation that the country will achieve a national production of 40 million bales by 2015 and a target of 100 million bales by 2030.

"Ten –significant milestones" were achieved in 2002-2011 that were presented in Brief 43. It provided a better understanding of the Bt cotton experience and an opportunity to emulate the success in the second decade of Bt cotton from 2012 to 2021.

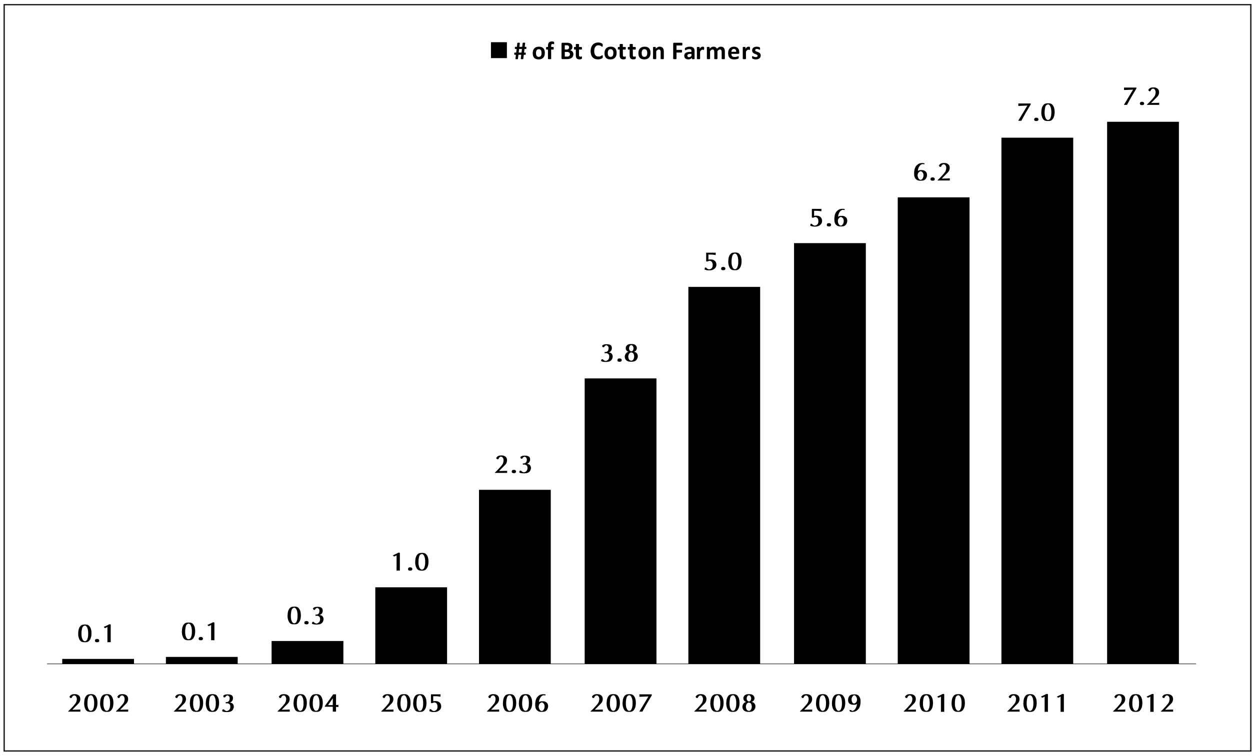
India is traditionally a cotton growing country with the largest hectarage of cotton of any country in the world. It accounts for approximately one third of the total cotton area planted in the world. Within India, 66% or a majority of cotton is grown in the Central cotton growing zone, mostly rainfed, in the States of Maharashtra, Gujarat, Madhya Pradesh and Odisha. Southern cotton growing zone including Andhra Pradesh, Karnataka and Tamil Nadu plant 22% of total cotton area with remaining 12% planted in Northern cotton growing regions of Punjab, Haryana and Rajasthan. The Central and Southern zone primarily grow the long duration cotton crop mostly in rainfed conditions and thus allow farmers to reap multiple harvests of the long staple cotton during the season. In contrast, the irrigated cotton in Northern zone is mostly a short duration crop that befits perfectly into the cotton-wheat cropping system.

Year 2011 set a new record of 12.1 million hectares of cotton cultivation in India – an attribute to the ever growing acceptance of Bt cotton hybrids by the Indian cotton farmers. Notably, India achieved unparalleled progress on three fronts: highest ever hectarage under cotton cultivation – 12.1 million hectares; largest ever production of cotton at 35.5 million bales and a sustained cotton yield of more than 500 kg per hectare despite significant increases in cotton hectarage. Based on the latest estimates, the total hectarage of cotton in India was 11.6 million hectares in 2012, approximately 0.5 million hectares lower than the 12.1 million hectare in 2011 and slightly higher than 11 million hectares in 2010. It is farmed by 7.6 million farmers in 2012, based on the latest official data that the average cotton holding per farm in India is 1.5 hectares. In the period 2002-03 to 2012-13, a large number of additional farmers preferred to grow cotton due to low cost of cultivation, superior yield and production and high income. As a result, the number of small farmers cultivating cotton increased significantly from 5 million in 2002-03 to ~7.6 million farmers in 2012-13, an increase of 2.6 million. Similarly, the number of farmers growing Bt cotton hybrids in India has increased from 50,000 in 2002 to 100,000 in 2003, 1 million in 2005, with over a two-fold increase of 2.3 million farmers in 2006, 6.3 million in 2010,7 million farmers in 2011 and 7.2 million farmers, in 2012 (Figure 17). This 7.2 million beneficiary small and resource-poor Bt cotton farmers represented approximately 95% of the total number of 7.6 million farmers who grew cotton in India in 2012-13. The adoption of Bt cotton hybrids by 7.2 million farmers is the optimal adoption for biotech cotton, similar to other mature biotech cotton markets of the USA and Australia. ISAAA Brief 43 (James, 2011) provides supplementary information detailing the profile of cotton crop including state-wise land holdings, distribution and production of cotton in India in 2010-11. Similarly, the multiple usages of cotton and its by-products as food, feed and fiber from 2002 to 2010 is featured in ISAAA Brief 42 (James, 2010).

Adoption of Bt Cotton Hybrids in India, 2002 to 2012

Bt cotton, which confers resistance to important insect-pests of cotton, was first adopted in India as hybrids in 2002. Year 2012 is "a-decade-plus one" year of biotech cotton in India. There were 54,000 farmers who grew approximately 50,000 hectares of officially approved Bt cotton hybrids for the first time in 2002 which doubled to approximately 100,000 hectares in 2003 (Figure 17). The Bt cotton area increased four-fold in 2004 to reach half a million hectares. In 2005, the area planted to Bt cotton in India continued to scale up reaching 1.3 million hectares, an increase of 160% over 2004. In 2006, the adoption record increased which continued with almost a tripling of the area of Bt cotton to 3.8 million hectares. This tripling in area was the highest percentage year-on-year

Figure 17. Numbers of Small Farmers Growing Bt Cotton in India, 2002 to 2012

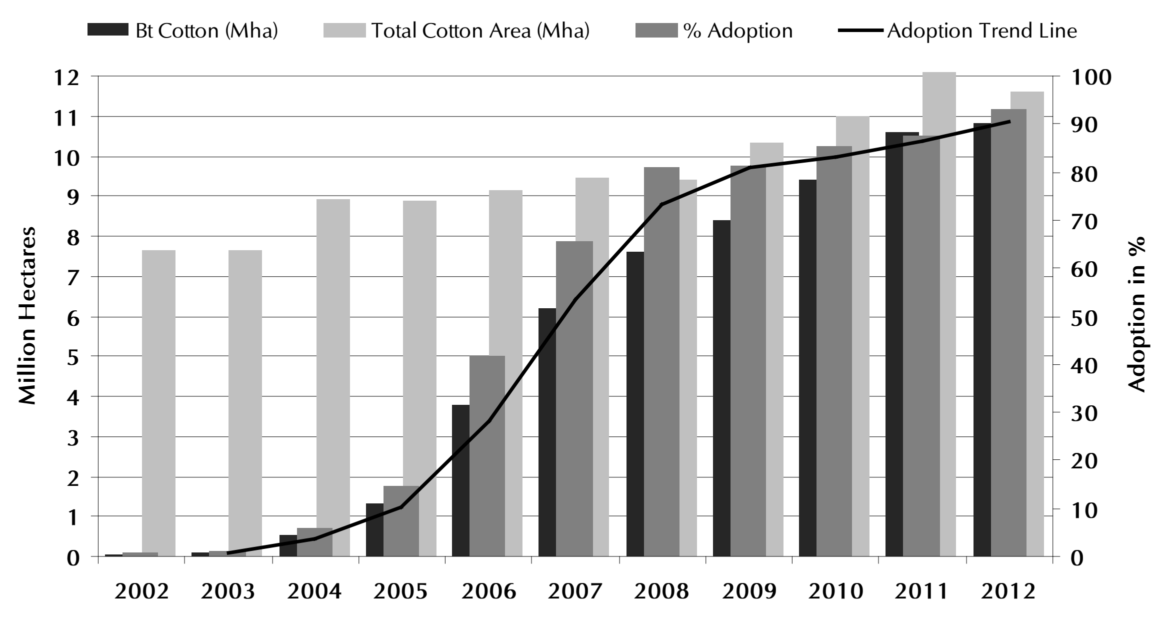


Source: Compiled by ISAAA, 2012.

growth for any country planting biotech crops in the world in 2006. Notably in 2006, India's Bt cotton area (3.8 million hectares) exceeded for the first time, that of China's 3.5 million hectares. In 2007, the Indian cotton sector continued to grow with a record increase of 63% in Bt cotton area from 3.8 to 6.2 million hectares, to become the largest hectarage of Bt cotton in any country in the world. In 2008, the Bt cotton area increased yet again to a record 7.6 million hectares from 6.2 million hectares in 2007. Maintaining double digit growth, the Bt cotton area increased to 8.4 million hectares in 2009, over 7.6 million hectares in the previous year. The high adoption of 81% in 2009 provided a solid platform to further support an increase in Bt cotton hybrid hectarage in 2010, which grew by over 10% to 9.4 million hectares which is equivalent to 85% of the total cotton area of 11 million hectares in 2010. In 2011, the adoption of Bt cotton surpassed the 10 million hectares mark reaching 10.6 million hectares by registering a robust 12.7% growth over previous year which was at all time high in the ten year period. Notably, an increase of 1.2 million hectares in 2011, when Bt cotton was already at 85% of its adoption in 2010 was driven by the increase in total cotton area from 11 million hectare in 2010 to 12.1 million hectare in 2011. In 2012, India registered a modest increase of 200,000 hectares on top of 10.6 million hectares of Bt cotton in 2011 to raise Bt cotton hectarage to 10.8 million equivalent to 93% adoption of the 11.6 million hectare cotton, an increase of 7% in 2012 from 88% in 2011 (Figure 18). Notably, the modest increase in Bt cotton area in the eleventh year of adoption indicates the deep penetration of Bt cotton to the smallest cotton farmers in sharp contrast to the overall steep reduction in total area under cotton from 12.1 million hectares in 2011 to an estimated 11.6 million hectares in 2012. The decrease by 0.5 million hectares of total cotton was due to erratic and late arrival of monsoon in 2012 *Kharif* season in the country that created a drought-like-situation at the time of sowing of cotton in the major parts of intensive cotton growing areas of Gujarat, Maharashtra, Karnataka and Northern cotton growing region.

Table 12 show the adoption and distribution of Bt cotton in the major growing states from 2002 to 2012. The major states growing Bt cotton in 2012, listed in order of hectarage, were Maharashtra (3,995 thousand hectares) representing 36% of all Bt cotton in India in 2012, followed by Gujarat (2,015 thousand hectares or 19%), Andhra Pradesh (1,935 thousand hectares or 18%), Northern Zone (1,390 thousand hectares or 13%), Madhya Pradesh (605 thousand hectares or 5.6%), and the balance in Karnataka, Tamil Nadu and other cotton growing States including Odisha. In the eleven year period, the adoption of Bt cotton has evenly spread across all the cotton growing States in the country. The high percentage adoption of Bt cotton by farmers across the different States reflects the priority of controlling the menace of the American bollworm complex, a group of deadly borer insects that caused heavy damage to cotton crop in the past. In 2012, 93% of the total cotton area was planted with Bt cotton, irrespective of the size, location and land holdings. The 93% adoption rate for Bt cotton in India in 2012 is the highest ever recorded in the country and compares favorably with 99.5% adoption for biotech cotton in Australia, 94% in the USA and 80% in China.

Figure 18. Eleven Years of Adoption of Bt Cotton Hybrids in India, 2002 to 2012



Source: Compiled by ISAAA, 2012.

Table 12. Eleven Years of Adoption of Bt Cotton in India, by Major States, 2002 to 2012 (Thousand Hectares)

State	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Maharashtra	25	30	200	607	1,840	2,800	3,130	3,396	3,710	3,960	3,995
Andhra Pradesh	8	10	75	280	830	1,090	1,320	1,049	1,650	1,820	1,935
Gujarat	10	36	122	150	470	908	1,360	1,682	1,780	1,930	2,015
Madhya Pradesh	2	13	80	146	310	500	620	621	610	640	605
Northern Region*	-	-	-	60	215	682	840	1,243	1,162	1,340	1,390
Karnataka	3	4	18	30	85	145	240	273	370	570	520
Tamil Nadu	2	7	5	27	45	70	90	109	110	220	220
Others	-	-	-	-	5	5	5	8	8	120	120
Total	**50**	**100**	**500**	**1,300**	**3,800**	**6,200**	**7,605**	**8,381**	**9,400**	**10,600**	**10,800**

Source: Compiled by ISAAA, 2012.

Over the years, there has been an increasing trend to adopt double gene Bt cotton hybrids by cotton farmers in India (Table 13). The first two-gene event MON15985, commonly known as Bollgard®II (BG®II) was developed by Mahyco and sourced from Monsanto, featured the two genes *cry1Ac* and *cry2Ab*, and was approved for sale for the first time in 2006 – four years after the approval of the single gene event MON531 Bt cotton hybrids in 2002-03. In the first year 2006-07, the double gene Bt cotton hybrids were planted on 0.15 million hectares whilst single gene Bt cotton hybrids occupied 3.65 million hectares equivalent to 96% of all the Bt cotton planted. In 2012, the double gene Bt cotton hybrid almost replaced the single gene Bt cotton hybrid with more than 90% area under double gene Bt cotton hybrids in 2012. It is noteworthy to mention that the double gene Bt cotton hybrids provide additional protection to *Spodoptera* (a leaf eating tobacco caterpillar) while it provides protection to both American bollworm, Pink bollworm and Spotted bollworm. It is reported that double gene Bt cotton farmers earn higher profit through cost savings associated with fewer sprays for *Spodoptera* control as well as increasing yield by 8-10% over single gene Bt cotton hybrids.

Approval of Events and Bt Cotton Hybrids in India, 2002 to 2012

Of the estimated 11.6 million hectares of cotton in India in 2012, 93% or 10.8 million hectares were Bt cotton hybrids – a remarkably high proportion of Bt cotton in a fairly short period of eleven years equivalent to an unprecedented 216-fold increase from 2002 to 2012. Of the 10.8 million hectares of Bt cotton hybrids, 35% was under irrigation and 65% rainfed. A total of 1097 introductions (1095 hybrids with the discontinuation of a hybrid and a variety of Event BNLA-601 since 2010) were approved for planting in 2012 compared with 884 Bt cotton hybrids in 2011, 780 in 2010, 522 in 2009, 274 in 2008, 131 in 2007, 62 in 2006, 20 in 2005 and only 4 Bt cotton hybrids in 2004.

Table 13. Adoption of Single and Double Gene Bt Cotton Hybrids in India, 2006 to 2012 (Millions Hectares and Percentage)

Number of Genes	2005	2006	2007	2008	2009	2010	2011	2012
Double	-	0.15 (4%)	0.46 (8%)	2.04 (27%)	4.82 (57%)	6.60 (70%)	8.70 (82%)	9.7 (90%)
Single	1.3 (100%)	3.65 (96%)	5.74 (92%)	5.56 (73%)	3.58 (43%)	2.80 (30%)	1.90 (18%)	1.1 (10%)
Total	1.3 (100%)	3.80 (100%)	6.20 (100%)	7.60 (100%)	8.40 (100%)	9.40 (100%)	10.6 (100%)	10.8 (100%)

Source: Compiled by ISAAA, 2012.

Over the last eleven years, India has greatly diversified deployment of Bt genes and genotypes, which are well-adapted to the different agro-ecological zones to ensure equitable distribution to small and resource-poor cotton farmers. Notably, India is the only country in the world that grows cotton hybrids for many years. The ICAR's Central Institute of Cotton Research, CICR Vision 2030 document released in 2011 noted the development of the first cotton hybrid as one of the most spectacular achievements that stands-out as a technology that had the greatest influence on cotton in India (CICR, 2011). In the first thirty years of hybridization from 1971 to 2001, a large number of cotton hybrids, both intra-specific and inter-specific cotton hybrids were released for commercial cultivation by both public and private sector institutions in the country. However, by 2001, the adoption of cotton hybrids reached only 45% of the total cotton area planted in 2001 – a year prior to the commercial release of Bt technology in India in 2002. In 2012, India occupied 10.8 million hectares under (Bt) cotton hybrids or 93% of total area planted with cotton, which is more than double the 45% cotton hybrid area occupied in 2001. The significant increase in area under hybrid cotton cultivation is credited to the introduction of Bt technology which spurred the hybridization of cotton from 3 Bt cotton hybrids in 2002-03 to 1095 Bt cotton hybrids in 2012 and at the same time, the area of cotton hybrids increased significantly to 93% in 2012 from 45% in 2001.

The number of events as well as the number of Bt cotton hybrids and companies marketing approved hybrids have all increased significantly from 2002, the first year of commercialization of Bt cotton in India. The Genetic Engineering Appraisal Committee (GEAC) of the Ministry of Environment and Forest (MOEF) approved six events of Bt cotton incorporating single and double genes in the eleven year period from 2002 to 2012. These events included MON531 featuring *cry1Ac* gene, followed by first two-gene event MON15985 featuring *cry1Ac* and *cry2Ab2*, Event-1 featuring cry1Ac, GFM event featuring fused genes *cry1Ab* and *cry1Ac*, BNLA-601 event featuring *cry1Ac* gene and finally MLS-921 featuring synthetic *cry1C* gene. The event BNLA-601 featuring *cry1Ac* gene in an open pollinated variety and a hybrid was the first event developed by public sector institutes in India was discontinued in 2010 and is under scientific validation and evaluation. Table 14 shows in order of chronology the year of approval, the details of each event, gene and developer of these six approved events for commercial cultivation in the country. ISAAA Brief 43 (James, 2011) provides detailed information about each of the six events approved for commercial cultivation in the country.

Out of the six approved events, four events were backcrossed with a large number of superior cotton genotypes and released for commercial plantings from 2002 to 2012. In 2012, a total of four events were approved for incorporation in a total of 213 hybrids in addition to the 884 Bt cotton hybrids approved for sale in 2011, for a total of 1095 Bt cotton hybrids (excluding one variety and a hybrid of event BNLA-601. This provided farmers in India's three cotton-growing zones significantly more choice of hybrids for cultivation in 2012. The commercial deployment of the first four events in hybrids is summarized in Appendix 3 and Appendix 4, and their regional distribution is detailed in Table 15.

Table 14. Commercial Release of Different Bt Cotton Events in India, 2002 to 2012

No.	Crop	Gene(s)	Event	Developer	Status	Year of Approval
1	Cotton*	*cry1Ac*	MON-531	Mahyco/Monsanto	Commercialized	2002
2	Cotton*	*cry1Ac* and *cry2Ab2*	MON-15985	Mahyco/Monsanto	Commercialized	2006
3	Cotton*	*cry1Ac*	Event-1	JK Agri-Genetics	Commercialized	2006
4	Cotton*	fused genes *cry1Ab* and *cry1Ac*	GFM Event	Nath Seeds	Commercialized	2006
5	Cotton**	*cry1Ac*	BNLA-601	CICR (ICAR) & UAS, Dharwad	Commercialized	2008
6	Cotton*	synthetic *cry1C*	MLS-9124	Metahelix Life Sciences	Commercialized	2009

*Bt cotton hybrid; ** A hybrid and a variety of Event BNLA-601 discontinued since 2010
Source: Compiled by ISAAA, 2012.

Table 15. Deployment of Approved Bt Cotton Events/Hybrids/Variety by Region in India, 2012

Event	North (N)	Central (C)	South (S)	North/ Central (N/C)	North/ South (N/S)	Central/ South (C/S)	N/C/S	Total Hybrids
BG-I[1]	42	52	42	14	1	53	13	217
BG-II[2]	142	154	146	11	11	211	59	734
Event-I[3]	9	8	7	0	0	17	1	42
GFM Event[4]	22	28	17	4	0	28	1	100
BNLA-601[5,**]	0	0	0	0	0	1	1*	2
MLS-9124[6]	0	0	0	0	0	2	0	2
Total	**215**	**242**	**212**	**29**	**12**	**312**	**75**	**1,097**

*Bt cotton variety
**Event BNLA-601 discontinued since 2010
[1,2] Mahyco [3] JK Seeds [4] Nath Seeds [5] CICR (ICAR) and [6] Metahelix
Source: Compiled by ISAAA, 2012.

In addition, there are five new cotton events that are undergoing biosafety assessment, contained field trial and open field testing which would be considered for commercial approval in India between 2013 to 2015 (Table 16). These new events would offer new biotech traits complementing the insect resistant Bt trait that has become integral part of the commercial cotton germplasm. The most promising "new trait" that would be made available to small farmers is the herbicide tolerant trait and stacking of herbicide tolerant trait with insect resistant Bt trait to continue the momentum of growth and prosperity to cotton farmers in the country with the expectation that the country achieve the target of 40 million bales by 2015. The herbicide tolerant trait in cotton is a long overdue trait to be commercialized in India which would impart tolerance to cotton plant against chemical herbicides. Weed causes a significant loss to cotton crop in the country. The herbicide tolerant cotton trait is the most desired biotech trait in the large cotton growing countries and would unlock a new hope for Bt cotton farmers in India by allowing farmers to efficiently control ubiquitous weeds, reduce labor cost, decrease erosion of fertile-soil and conserve moisture thereby increasing plant resilience to drought and substantially increase cotton productivity and production.

Table 16. Bt and Bt/HT Cotton Events Field-tested and Pending Approval for Commercialization in India, 2012-2015

No.	Crop	Event	Developer	Status	Year of Approval
1	Cotton	MON 15985 × MON 88913	Mahyco/Monsanto	Field Tested	2013
2	Cotton	Widestrike Event 3006-210-23 and Event 281-24-236	Dow AgroSciences, Mumbai	Field Tested	–
3	Cotton	Event 1 and Event 24	JK Agri Genetics Ltd., Hyderabad	Field Tested	–
4	Cotton	*2mEPSPS* gene	Bayer Biosciences Pvt. Ltd.	Field Tested	–
5	Cotton	MON 15985 × COT-102 × MON 88913 × MON 76366	Monsanto	Field Application	–

Source: Compiled by ISAAA, 2012.

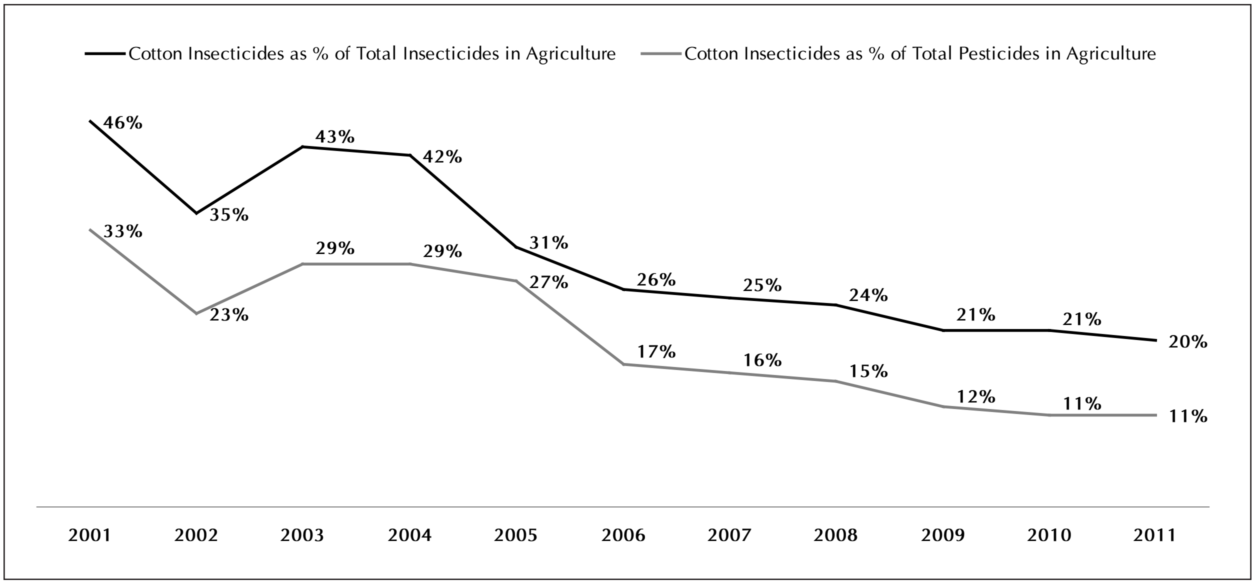
Savings of Insecticides due to Bt Cotton, 2001 to 2012

Traditionally, cotton consumed more insecticides than any other crop in India and was a significant proportion of the total pesticide (insecticides, fungicides and herbicides) market for all crops. For example, of the total pesticide market in India in 2001 valued at US$713 million (Figure 19 and Table 17), 33% was for cotton insecticides only, which were equal to 46% of the total insecticide market for all crops in India (Kranthi, 2012). Subsequent to the introduction of Bt cotton, cotton consumed only 18% of the total pesticide market, in 2006, valued at US$900 million as compared to a much higher 30% in 1998. Similarly, the market share for cotton insecticides as a percentage of total insecticides declined from 46% in 2001, to 26% in 2006 and to 20% in 2011. The percentage of cotton insecticides to the total insecticides used in agriculture in India halved to 20% in 2011 from 46% in 2001, prior to the introduction of Bt cotton in India in 2002. At the macro-level, the percentage of cotton insecticides to the total pesticides market in India registered a steep decline from 33% in 2001 to 11% in 2011 at the time when total pesticides market in the country more than doubled from US$713 million in 2001 to more than US$1,707 million in 2011.

Figure 19 reports a consistent downward trend in the consumption of cotton insecticides measured as percentage of the total insecticides and pesticides used in agriculture in India from 2001 to 2011. The steep reduction in the percentage of cotton insecticides/pesticides as a percentage of total insecticides/pesticides in agriculture dropped to 20% and 11%, respectively, in 2012 from highs of 46% and 33% in 2001. Notably, there has been a very steep decline in insecticide usages on *Helicoverpa armigera* from 71% in 2001 to 3% in 2011. Interestingly, cotton farmers in India hardly need to spray insecticides to control bollworm in Bt cotton field, in contrast to conventional cotton farm which required dozens of spraying to control bollworm, prior to introduction of Bt cotton in the country in 2002. This is by far the largest positive impact by reducing bollworm insecticides from 71% in 2001 to 3% in 2011. Figure 20 shows the percentage reduction of insecticides on cotton bollworm relative to total insecticides used in cotton in India from 2001 to 2011. Contrary to the trend in cotton insecticides, the total usage of insecticides in agriculture increased significantly from US$504 million in 2001 to US$952 million in 2010. A steep decline in the percentage of insecticides applied on cotton to total insecticides used in agriculture is a clear sign of relief to cotton growers and laborers in the country who traditionally suffered from the intensive use of insecticides to control a major cotton enemy – American bollworm complex, which is now effectively controlled by Bt cotton technology.

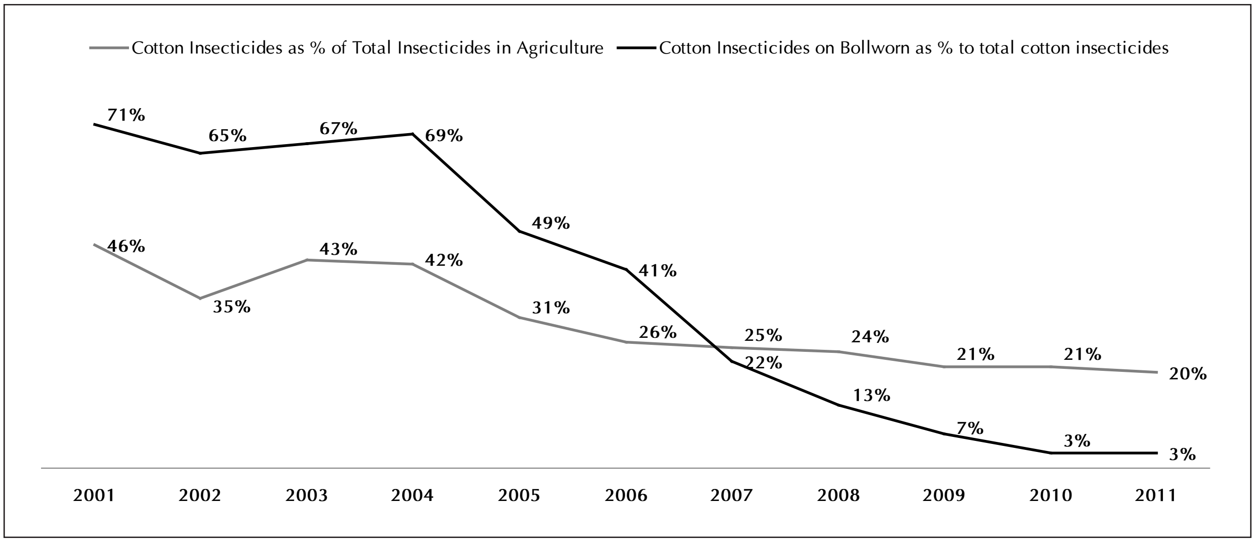
This saving in insecticides between 2004 and 2010 coincided with the large scale adoption of Bt cotton from half a million hectares in 2004 to 10.6 million hectares in 2011-12, equivalent to 88% of the hectarage of the cotton crop in 2011-12. More specifically, the sharpest decline in insecticides occurred in the bollworm market in cotton in terms of value, which declined from US$160 million in 2004 to US$25 million in 2010 – an 85% decrease, equivalent to a saving of US$135 million

Figure 19. Percentage Reduction of Insecticides on Cotton Relative to Total Insecticides/ Pesticides Used in Agriculture in India, 2001 to 2011



Source: Kranthi, 2012; CIBRC, 2012; Compiled by ISAAA, 2012.

Figure 20. Percentage Reduction of Insecticides on Cotton Bollworm Relative to Total Insecticides Used in Cotton in India, 2001 to 2011



Source: Kranthi, 2012; CIBRC, 2012; Compiled by ISAAA, 2012.

Table 17. Value of the Total Pesticide Market in India in 2001 and 2010 Relative to the Value of the Cotton Insecticide Market

Item/Year	2001	2006	2010
Total pesticide market (in million US$)	US$713 million	US$748 million	US$1,707 million
Cotton insecticides as % of total pesticide market	33%	17%	11%
Total insecticide market (in million US$)	US$504 million	US$404 million	US$952 million
Cotton insecticides as % of total insecticide market	46%	26%	21%
Value in US$ millions of cotton bollworm market & (savings due to Bt cotton) in 2004 over 2010	US$160 million (in 2004)	-	US$25 million (Savings of US$135 million, or 85%, compared with 2004)

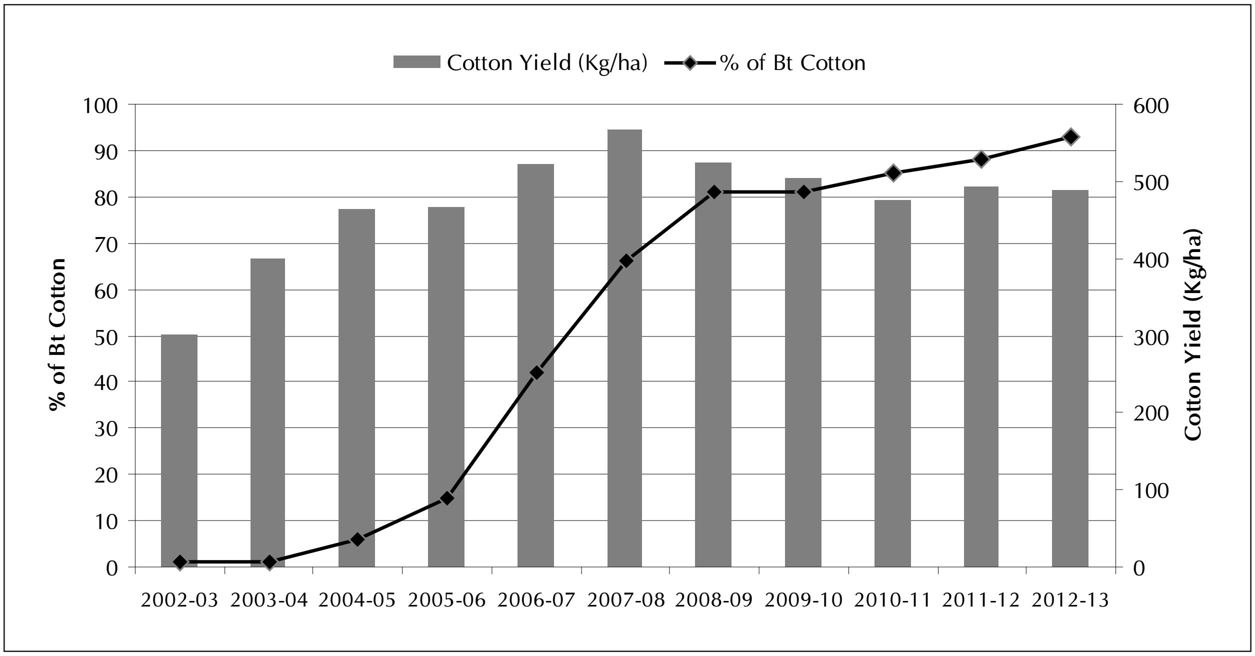
Source: Kranthi, 2012; CIBRC, 2012; Compiled by ISAAA, 2012.

in the use of insecticides to control cotton bollworm in 2010. Similarly, the quantity of insecticides used to control bollworm reduced by 96% from 5748 metric tons of active ingredients in 2001 to as low as 222 metric tons of active ingredients in 2011. Thus, insecticide use for the control of bollworm dropped significantly at the same time when approximately 88% of the cotton area in 2011 (10.6 million hectares) was benefiting from controlling bollworm with Bt cotton.

Cotton Production, Yield and Imports/Exports, Since the Introduction of Bt Cotton in 2002

The commercial approval of Bt cotton in 2002 was a breakthrough step to revive the ailing cotton sector in the country – stagnation in cotton production, decelerating trend in cotton yield and overreliance on cotton import for over many decades. Coincidental with the steep increase in adoption of Bt cotton between 2002 and 2011, the average yield of cotton in India, which used to have one of the lowest yields in the world, increased from 308 kg per hectare in 2001-02, to 567 kg per hectare in 2007-08 and continue to hover close to 500 kg per hectare in 2011-12; cotton production increased from 13.6 million bales in 2002-03 to 35.3 million bales in 2011-12, which was a record cotton crop for India. At the same time, the country was transformed from a net importer of raw cotton until 2002-03 to net exporter of cotton. Figure 21 shows the upward trend in cotton yield which remained stagnant at 300 kg per hectare until the introduction of Bt technology in 2002-03. The cotton yield almost doubled from 302 kg per hectare in 2002-03 to 567 kg per hectare in 2007-08 and was correlated with the large scale adoption of Bt cotton in the major

Figure 21. Impact of Adoption of Bt Cotton on Cotton Yield in India, 2002 to 2012



Source: Cotton Advisory Board, 2012; Compiled by ISAAA, 2012.

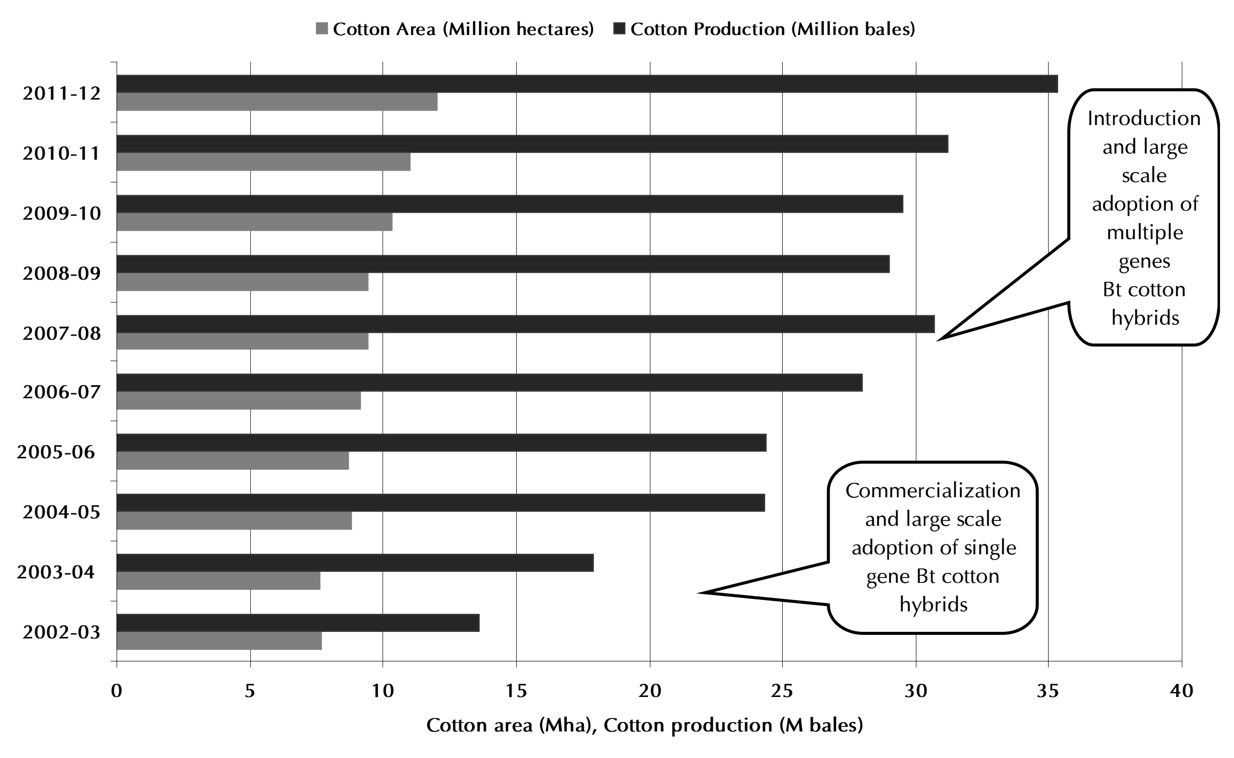
cotton growing areas; yields remained at approximately 500 kg per hectare from 2008 to 2011 with seasonal variation due to many factors. In 2011-12, cotton yield remained as high as 493 kg per hectare despite the fact that there was a substantial increase in cotton area in the last two years including relatively more marginal land under cotton cultivation. It is expected that cotton yield would remain above 490 kg per hectare in 2012-13 season (Figure 21).

It is clear that at the national level, Bt cotton has been a major factor contributing to higher cotton production which increased from 15.8 million bales in 2001-02, to 24.4 million bales in 2005-06, 28 million bales in 2006-07, and 31.5 million bales in 2007-08, which was a record cotton crop for India (Cotton Advisory Board, 2008). Subsequently, cotton production declined to 29 million bales in 2008-09 before again showing an upward trend to 29.5 million bales in 2009-10 seasons due to prevailing unfavorable climatic condition in 2008 including a delayed monsoon with erratic rainfall and flooding at the time of boll maturity and cotton picking in the Central and Southern cotton growing zones in 2009.

The Cotton Advisory Board reported higher cotton production to 31.2 million bales in 2010-11 and the largest ever cotton production of 35.3 million bales in India for 2011-12 – this is a significant increase in overall cotton production over 2011 and the previous years. The cotton production continues to soar above 33 million bales with a projected cotton production of 33.4 million bales in 2012-13 (CAB, 2012). This quantum leap in cotton production since 2002-03 has been due to improved seeds particularly the ever-increasing hectarage of improved Bt cotton hybrids in the ten cotton-growing states. The first phase of substantial gains were realized with the large scale adoption of the single gene Bt cotton hybrids from 2002-03 to 2006-07. The impact of second generation double genes Bt cotton hybrids was associated with the largest ever cotton production gains culminating in 35.3 million bales in India in 2011-12 (Figure 22). Recognizing the remarkable progress achieved in cotton production in the last ten years, India's Ministry of Agriculture has invested in R&D, infrastructure and human resource development in order to harness the full potential of biotechnology in agriculture in the coming years.

With the boom in cotton production in the last eleven years, India is transformed from a net importer to a net exporter of cotton. Exports of cotton have registered a sharp increase from a meager 0.05 million bales in 2001-02 to 5.8 million bales in 2006-07 before touching a high of 8.8 million

Figure 22. Cotton Hectarage and Production in India, 2002 to 2012



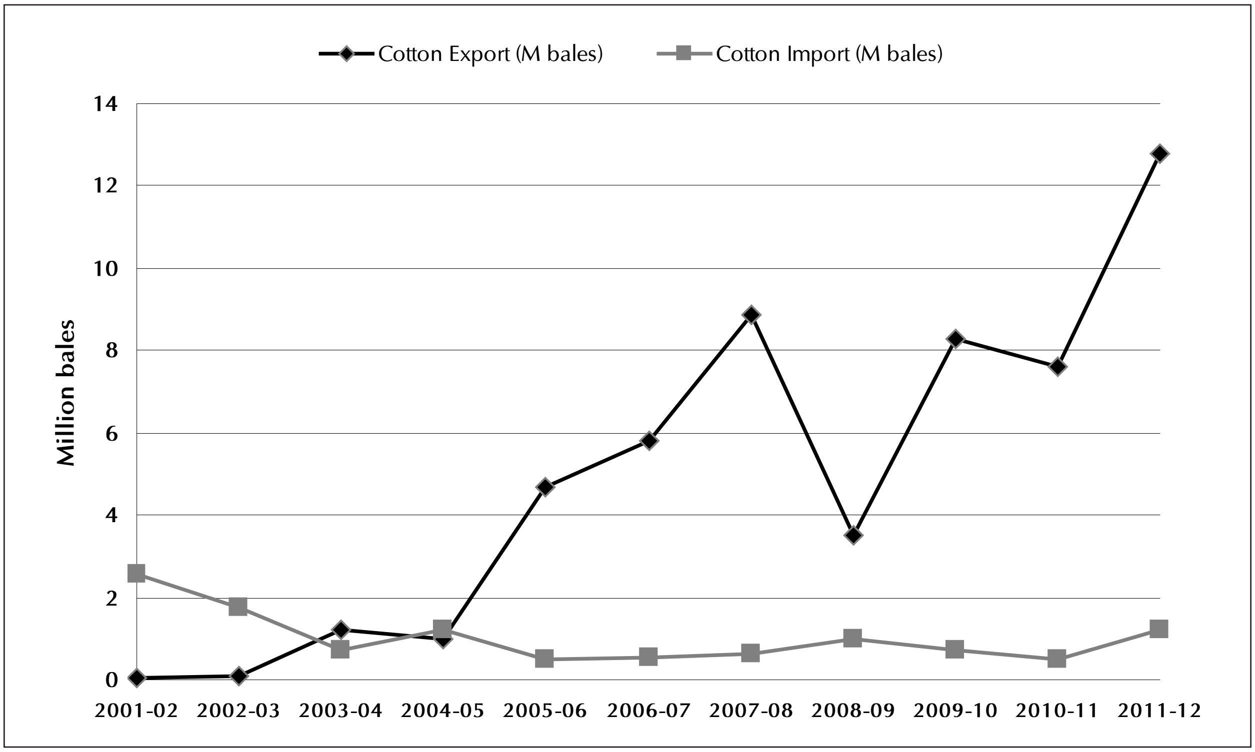
(1 Bale = 170kg)

Source: CAB, 2012; Compiled by ISAAA, 2012.

bales in 2007-08 (PIB, 2007). As per the latest Cotton Advisory Board (CAB) report, the raw cotton export rebounded from 7.6 million bales in 2010-11, a marginally down from its previous year to the highest recorded raw cotton export of 12.8 million bales in 2011-12 amidst unpredictable policy environment on export of raw cotton in the country. India is the world's largest cotton exporting country with recorded 12.8 million bales of export of raw cotton in 2011-12 (Figure 23) (PIB, 2012).

Other notable contribution of Bt cotton is to enhance the supply of medium-long staple cotton due to the large scale adoption of hybrid genotypes with medium to long staple length over the cultivation of local or desi cotton varieties in the past. The unprecedented increase in availability of the long staple and extra-long staple cotton has helped in meeting demand of the major raw material by the cotton mills of the textile industry. The volume of long staple cotton production registered more than five-fold increase from 5.1 million bales in 2002-03 to 26.6 million bales in 2011-12 (Figure 24). Notably, the long and extra long staple cotton are the premium category of cotton that spins high quality yarn for manufacturing the high value added cotton textile products in the country.

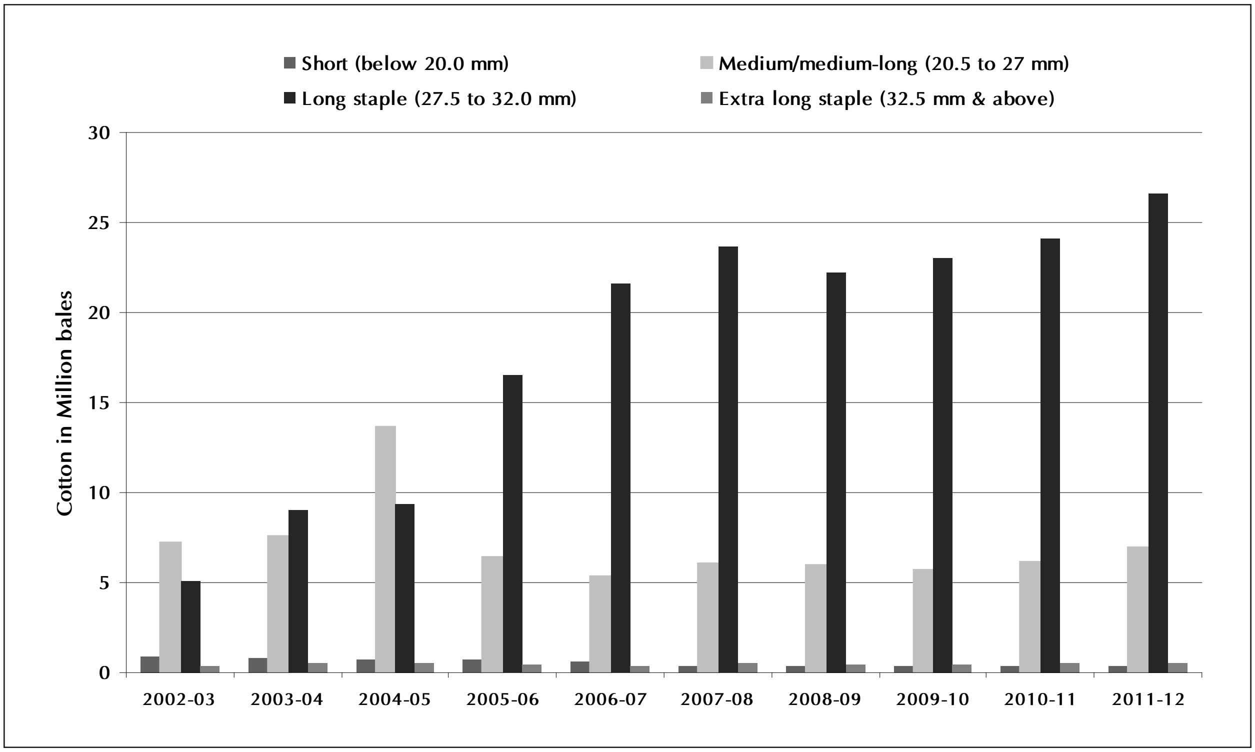
Figure 23. Export and Import of Cotton in India, 2001 to 2012



(1 Bale = 170kg)

Source: Cotton Advisory Board, 2012; Cotton Corporation of India, 2012.

Figure 24. Growth of Long Staple Cotton in India, 2002 to 2012



Source: Cotton Corporation of India, 2012.

Impact and Socio-Economic Benefits from Bt Cotton in India, 2002 to 2012

The annual global study of benefits generated by biotech crops, conducted by Brookes and Barfoot (2013, Forthcoming), estimated that India enhanced farm income from Bt cotton by US$12.6 billion in the period 2002 to 2011 (ten- year period) and US$3.2 billion in 2011 alone. Typically, yield gains are approximately 31%, a significant 39% reduction in the number of insecticide sprays, leading to an 88% increase in profitability, equivalent to a substantial increase of approximately US$250 per hectare (Gandhi and Namboodiri, 2006). Thus, Bt cotton has transformed cotton production in India by increasing yield, decreasing insecticide applications and through welfare benefits, contributed to the alleviation of poverty for over 7 million small resource-poor farmers in 2011.

In addition to the annual global socio-economic study conducted by Brookes and Barfoot (2013, Forthcoming), a large number of socio-economic benefits and impact studies were conducted by researchers from within and outside India. These studies employed different econometric modelling and socio-analytic methodologies that covered a range of impact parameters including production and yield, cost of cultivation, profitability, employment, income, expenditure, gender and household living standards. These studies, summarized in Table 18, and briefly reviewed at the end of this chapter, have been covered in detail in previous ISAAA Briefs and readers are referred to them. In this Brief, a selection of most recent studies published in 2012 are selected and discussed in the following paragraphs.

In 2012, Kathage & Qaim, researchers at the Georg-August-University of Goettingen published a research study **"Economic impacts and impact dynamics of Bt (*Bacillus thuringiensis*) cotton in India"** in the Proceedings of the National Academy of Sciences (PNAS). The study confirms that Bt has contributed to a 24% increase in cotton yield per acre and a 50% gain in cotton profit among smallholders. Furthermore, Bt cotton adoption has raised consumption expenditures, a common measure of household living standard, by 18% during the 2006–2008 periods. The study reports that the benefits are stable and Bt increases net profit of US$107 per acre to annual farm-level cotton profits during 2002–2004 and US$213 per acre during 2006–2008. ***"Nationwide, for the 26 million acres currently under Bt, this implies an annual net gain of almost 50 billion Rs (US$ 1 billion in cotton profits."*** The study concludes that ***"Bt cotton has created large and sustainable benefits, which contribute to positive economic and social development in India. Nonetheless, our results clearly refute the assertion that Bt technology would harm smallholder farmers because of low and eroding economic benefits"*** (Kathage & Qaim, 2012).

In 2012, the Bharat Krishak Samaj (BKS), a leading farmers' organization in India in collaboration with the Council for Social Development (CSD) published a study on the **"Socio-Economic Impact Assessment of Bt Cotton in India"** (Farmers' Forum, 2012). This is the first major study on Bt cotton by any farmer organization in the country. The BKS/CSD study confirms that ***"cotton production in India has risen substantially with the use of the hybrid Bt cotton seeds resulting in benefiting small farmers and helping the country to become net exporter of cotton in the world. The overall production of cotton has grown by 9.25 percent since introduction of Bt cotton in 2002-03 and farmers' income jumped up by nearly 375 percent."*** In line with other twelve studies conducted both pre and post commercialization of Bt cotton in 2002, the BKS study also reports a steep decline in pesticide consumption by 23 percent in the post-Bt cotton period. Similarly, the study also reports a substantial gain to small farmer for growing Bt cotton, with an average net returns from Bt cotton at the all India level to be as high as Rs.65307.82 (US$1300 per hectare). The per hectare net returns were scale neutral across farm size classes. Further, it was also found that the total income or net returns from Bt cotton was much higher than income from other non-farm sources. On the Socio-Economic front, the study reported that the increased returns from Bt cotton have had a significantly positive effect on the livelihood status of farmers and landless laborers. The study noted that ***"On an average 85 percent farmers and landless laborers invested in better quality education for their children, 77 percent reported intake of high value and nutritious***

food, 70 percent in recreation and social functions, 75 percent on health of their family members and 64 percent on health of livestock" (Farmers' Forum, 2012).

An overview of the twelve studies as referenced chronologically in Table 18 conducted by public sector institutions on the benefits and socio-economic impact of Bt cotton in India from 1998 to 2011 have been reported in the ISAAA Brief 43 (James, 2011). It included three studies conducted prior to the commercialization of Bt cotton from 1998 to 2001 and nine studies reported post commercialization of Bt cotton from 2002 to 2011. The results of these studies on Bt cotton were consistent with the study undertaken by Gandhi and Namboodiri in 2006 showing yield gains of approximately 31%, a significant 39% reduction in the number of insecticide sprays, leading to an 88% increase in profitability, equivalent to a substantial increase of approximately US$250 per hectare (Gandhi and Namboodiri, 2006). In addition, the only published impact studies of Bt cotton in 2008/09 was conducted by IMRB International (IMRB, 2009) which focused on the agronomic and economic benefits. The only published study specifically on the social impact of Bt cotton was conducted by Indicus Analytics in 2007 (Indicus, 2007).

Political Will and Support

In October 2012, the Scientific Advisory Council (SAC) to the Prime Minister deliberated on the important issue of application of biotechnology for social and economic advancement of the country particularly in the area of agriculture. The committee emphasized that the ***"strategies for agriculture in future must be based on higher yields, concomitant with reduction in resource inputs. This will require a judicious blend of traditional breeding and new technologies, non-transgenic & transgenic. This situation in developed countries such as in Europe; quite in contrast, as there is no dearth of food and a small proportion of people engage in agriculture."*** The SAC noted that ***"there are uncertainties in some segments of society that need to be objectively and fairly addressed. A science informed, evidence based approach is lacking in the current debate on biotechnologies for agriculture."***

"The assessment of safety and efficacy of biotechnology products has to be evaluated through an appropriate regulatory system on a case-by-case basis, as for drugs and vaccines. In general, endorsement or opposition to a generic technology is scientifically not rational, and safety and efficacy must be judged on product basis. The need for an appropriate regulatory mechanism in the country has been rightly emphasized in the Swaminathan Committee Report. The existing system based on RCGM and GEAC have given us large experience and its operational guidelines are generally sound and as per the best international norms such as guidelines by OECD. The effort now should be on effective implementation. Regulatory systems evolve with experience and review based redesign. Little is served by focusing on

Table 18. Twelve Studies Conducted by Public Institutes on the Benefits of Bt Cotton in India for the Years, 1998 to 2010

Publication	[1]Naik 2001	[2]ICAR field trials 2002	[3]Qaim 2006	[4]Bennet 2006	[5]IIMA 2006	[6]ICAR FLD 2006	[7]Andhra University 2006	[8]CESS 2007	[9]Subramanian & Qaim 2009	[10]Sadashivappa & Qaim 2009	[11]Qaim *et. al* 2009	[12]Subramanian & Qaim 2010
Period studied	1998-99 & 00-01	2001	2001-2002	2002 & 2003	2004	2005	2006	2004-05	2004-05	2006-07	1998-06	2006-07
Yield increase	38%	60-90%	34%	45-63%	31%	30.9%	46%	32%	30-40%	43%	37%	43%
Reduction in no. of spray	4 to 1 (75%)	5-6 to 1 spray (70%)	6.8 to 4.2 (50%)	3 to 1	39%	–	55%	25%	50%	21%	41%	21%
Increased profit	77%	68%	69%	50% or more gross margins	88%	–	110%	83%	–	70%	89%	134%
Average increase in profit/hectare	$76 to $236/ hectare	$96 to $210/ hectare	$118/ hectare	–	$250/ hectare	–	$223/ hectare	$225/ hectare	$156/ hectare or more	$148 / hectare or more	$131/ hectare or more	$161/ hectare or more

Sources:

1. Naik G. 2001. "An analysis of socio-economic impact of Bt technology on Indian cotton farmers," Centre for Management in Agriculture, IIMA, India.
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11. Qaim M, A Subramanian and P Sadashivappa. 2009. Commercialized GM crops and yield, Correspondence, Nature Biotechnology. 27 (9) (Sept 2009).
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the flaws only," noted the Scientific Advisory Council. The SAC recommended many step including a reform in current regulatory system under EPA Rules 1989 till BRAI is in place; RCGM and GEAC should be the sole authority for biosafety and bio-efficacy assessment; High Level dialogue with State governments to streamline clearances for conduct of trials; A Biotechnology Regulatory Secretariat for GEAC/RCGM and GEAC and RCGM should have full time Chairpersons (SAC, 2012).

Addressing the inaugural of the COP-MOP6 on 1 Oct 2012, Smt. Jayanthi Natarajan, Minister of Environment and Forests recognizes ***"India is a mega diverse country with a strong and vibrant biotechnology industry and, therefore, committed to the implementation of the CPB in a balanced manner."*** Furthermore, she stated that ***"there are no short-cuts in achieving this balance. LMO is a controversial issue with concerns on long-term impact on ecology and conservation. We need to follow the protocol in letter and in spirit."*** She pointed out that investments in biotechnology were increasing significantly in several countries and there was need for science-based regulation in this regard (COP-MOP6, 2012; Hans India, 2012).

India's agriculture minister Mr. Sharad Pawar said that the lack of a cohesive governmental policy on genetically modified (GM) crops could harm India's long-term food security. In an exclusive interview to newspaper Hindustan Times on 14th Sept 2012, Mr. Pawar remarked that a squeamish policy had ***"totally demoralized"*** government scientists while stifling private initiatives, both of which were critical for keeping pressure off food availability for a growing population. Government scientists need "direction", he said, because technologies take years to develop. "***All this has serious food security implications"*** (Hindustan Times, 2012).

In another press release, Agriculture Minister Pawar stated that ***"Out of all the modern tools in crop science, biotechnology offers the maximum potential to address the issue of increasing genetic potential of building resilience to changing agro-climatic conditions and, above all, of increasing productivity on environmentally sustainable basis. It is, therefore, essential that adequate and fair opportunity is given to scientific efforts to develop GM crops."*** Further he stated that ***"Any hesitation on our part to prevent the further development of this technology on unfounded apprehension would not only demoralise our scientific community but also render meaningless the progress made by us so far and increase our future dependence on other countries where research in transgenic is being given more and more importance"*** (Deccan Herald, 30 October 2012).

While speaking during the conference "Decade of Bt Cotton in India – A Review" organized jointly by Centre for Environment Education (CEE), Centre for Sustainable Agriculture (CSA) & Council for Social Development (CSD) on 11-12 June 2012, Mr Jairam Ramesh, former Minister of Environment and Forests and the Union Minister for Rural Development noted that there has been a "structural transformation" in the cotton economy in India in the past two decades. ***"Bt cotton is certainly***

not a failure. Bt cotton has contributed, however it is not also completely responsible for the structural transformation in cotton; there are a large number of serious scientific questions that still persist" he said. The minister also noted that ***"the public sector investment in biotechnology is absolutely essential. Biotechnology has a large portfolio of interventions, and not just genetic engineering for increasing productivity in crops. We need to keep our options open as a country and make our investment in other fields and not concentrate our attention only in transgenic crops"*** (CSD, 2012).

CHINA

In 2012, China successfully grew approximately 4 million hectares of Bt cotton, ~6,275 hectares of virus resistant papaya in Guangdong province and Hainan Island and ~500 hectares of Bt poplar. Consistent with a ~10 to 15% decrease in total global cotton hectarage to ~32 million hectares in 2012, China also planted less cotton in 2012. Total cotton plantings were estimated at 4.933 million hectares, compared with ~5.5 million hectares in 2011. Adoption rate of Bt cotton in China was estimated at 80% in 2012 when 3.946 million hectares of Bt cotton were planted by 7.2 million small farmers. Economic gains at the farmer level from Bt cotton for the period 1997 to 2011 was US$13 billion and US$2.2 billion for 2011 alone. In 2012, an estimated 7.2 million small, resource-poor farmers in China continued to benefit from planting ~4.0 million hectares of Bt cotton. Research in northern China indicates that there maybe up to an additional 10 million beneficiary farmers cultivating 22 million hectares of crops other than cotton, which also host cotton bollworm, but where infestations have decreased up to ten-fold, because of lower infestations due to Bt cotton. Thus, the actual number of beneficiary farmers of biotech Bt cotton in China may well exceed 17 million.

Whereas rice is the most important food crop in China, maize is the most important feed crop, and biotech phytase maize has been assigned high priority by the Government of China. Over 32 million hectares of maize is grown in China by an estimated 100 million maize-growing households (~400 million potential beneficiaries). Phytase maize, which confers increased phosphate uptake by animals can increase the efficiency of meat production – an important new and growing need, as China becomes more prosperous and consumes more meat which requires more expensive imports of maize. China has 500 million pigs (~50% of the global swine herd) and 13 billion chickens, ducks and other poultry which need feed.

CHINA

Population: 1,336.3 million

GDP: US$4,327 billion

GDP per Capita: US$3,270

Agriculture as % GDP: 11%

Agricultural GDP: US$476 billion

% employed in agriculture: 41%

Arable Land (AL): 143.5 million hectares

Ratio of AL/Population*: 0.45

Major crops:

- Rice, paddy
- Maize
- Sugarcane
- Vegetables, fresh
- Sweet potato
- Cotton

Commercialized Biotech Crops:

- Bt Cotton
- VR Sweet Pepper
- Bt Poplar
- PRSV Papaya
- DR, VR Tomato

Total area under biotech crops and (%) increase in 2012:
4 Million Hectares (+3%)

Increased farm income for 1997-2011: US$13 billion

*Ratio: % global arable land / % global population

Given the significant increased demand for maize, and rising imports it is likely that biotech maize, as a feed crop, will be commercialized by China in the near term. China recently reiterated the strategic importance of biotech crops to the country and its commitment to ensure safe testing of the products before deployment. Biotech phytase maize and Bt rice approved for biosafety on 27 November 2009, are undergoing extensive and rigorous field trials that all new improved crops, conventional and biotech, must undergo prior to commercial approval.

Biotech maize and rice offer significant benefits and have momentous implications for China, Asia and the world in the near, mid and long term, because rice is the most important food crop in the world and maize the most important feed crop in the world. In China alone, Bt rice can benefit 110 million rice households totaling 440 million beneficiaries, assuming four per family. With 250 million rice-growing households in Asia, the number of potential beneficiaries of biotech rice is a momentous 1 billion people. Rice yield in China in 2009 was 6.59 tons/ha with national production at 197 million tons. China needs to increase its rice yield to 7.85 tons per hectare and 235 million tons production respectively by 2030, to meet the demand of its population of 1.6 billion. China's demand of 235 million tons of paddy in 2030, is equivalent to one third of global production of 750 million tons.

China has also approved and successfully grown biotech papaya, a fruit food crop for six years, since 2007. In 2012 in Guangdong province, the principal province

in China for papaya, 95% of the 4,500 hectares of papaya, equivalent to 4,275 hectares were biotech papaya, resistant to the lethal papaya ring spot virus (PRSV) disease. In 2012 for the first time, virus-resistant biotech papaya was also grown on 40% of the 5,000 hectares, equivalent to 2,000 hectares in Hainan Island for a total national hectarage in China of 6,275 hectares. Thus, China has increased its absolute hectarage of PRSV papaya to a record 6,275 hectares in 2012, an 18% increase over the 5,300 hectares in 2011. In Guangdong province adoption in 2012 was 95%, approximately the same as 2011, having increased from 90% in 2009, 88% in 2008, and 70% adoption, equivalent to 3,550 hectares in 2007 when it was first commercialized in China. It is noteworthy that Japan approved biotech papaya for import and marketing as a fresh fruit/food from the US in 2011. In addition, plantations of Bt poplar in China, with improved insect resistance, continued to be successfully grown on 491 hectares, a similar hectarage to that reported for 2011.

The Chinese Government's assignment of high priority to agriculture, and more specifically to crop biotechnology, championed by former Premier Wen Jiabao, is strategically extremely important for China, particularly in relation to its two premier food and feed crops, biotech rice and maize. This exertion of leadership and high priority for crop biotechnology also reflects China's increasing academic excellence in crop biotechnology. Agricultural science is China's fastest-growing research field, with China's share of global publications in agricultural science having more than tripled from 1.5% in 1999 to 5% in 2008. In 1999, China spent only 0.23% of its agricultural GDP on agricultural R&D, but this increased to 0.8% in 2008 and is now close to the 1% recommended by the World Bank for developing countries. The new target for the Chinese Government is to increase total grain production to 540 million tons by 2020 and to double Chinese farmers' 2008 income by 2020, with biotech crops expected to provide an important contribution.

In November 2009, China completed its approval of a troika of key biotech crops – fiber (Bt cotton already approved in 1997), feed (phytase maize) and food (Bt rice). China's Ministry of Agriculture (MOA) granted three biosafety certificates on the same day. Two certificates were issued for biotech rice, one for a rice variety (Huahui-1) a restorer line, and the other for a hybrid rice line (Bt Shanyou-63), both of which expressed *cry1Ab/cry1Ac* and developed at Huazhong Agricultural University (James, 2009a). The approval of Bt rice is extremely important because rice is the most important food crop in the world that feeds 3 billion people or almost half of humanity; furthermore and importantly, rice is also the most important food crop of the poor. The third certificate was for biotech phytase maize; this is also very important because maize is the most important animal feed crop in the world. The phytase maize was developed by the Chinese Academy of Agricultural Sciences (CAAS) and licensed to Origin Agritech Limited after 7 years of study at CAAS. **The three**

certificates of approval have momentous positive implications for biotech crops in China, Asia and the whole world in the near, mid and long term. It is important to note that the MOA conducted a very careful due diligence study, prior to issuing the three certificates for full commercialization, pending completion of the standard registration field trials which applies to all new conventional and biotech crops. It is noteworthy that China has now completed approval of a troika of the key biotech crops in an appropriate chronology – first was FIBER (cotton), followed by FEED (maize) and FOOD (rice). The potential benefits of these 3 crops for China are enormous and summarized below.

- **Bt cotton.** China has successfully planted Bt cotton since 1997 and in 2012, 7.2 million small farmers in China increased their income by approximately US$220 per hectare (equivalent to approximately US$1 billion nationally) due, on average, to a 10% increase in yield, and a 60% reduction in insecticides, both of which contribute to a more sustainable agriculture and the prosperity of small poor farmers. China is the largest producer of cotton in the world, with an estimated 80% of its 5 million hectares successfully planted with Bt cotton in 2012.

- **Phytase maize.** China, after the USA, is the second largest grower of maize in the world (> 32 million hectares grown by 100 million households); it is principally used for animal feed. Achieving self-sufficiency in maize and meeting the increased demand for more meat in a more prosperous China is an enormous challenge. For example, China's swine herd, the biggest in the world, increased 100-fold from 5 million in 1968 to over 500 million today. Phytase maize will allow pigs to digest more phosphorus, resulting in faster growth/more efficient meat production, and coincidentally result in a reduction of phosphate pollution from animal waste into soil and extensive bodies of water and aquifers. Maize is also used as feed for China's huge number of domesticated avian species – 13 billion chickens, ducks and other poultry, up from 12.3 million in 1968. Phytase maize will allow animal feed producers to eliminate the need to purchase a phytase supplement with savings in equipment, labor and added convenience. The significance of this maize approval is that China is the second largest grower of maize in the world with >30 million hectares (USA is the largest at 37 million hectares). As wealth is rapidly being created in China, more meat is being consumed which in turn requires significantly more animal feed of which maize is a principal source. China imports 5 million tons annually at a foreign exchange cost of over US$1 billion. It is noteworthy that phytase maize is China's first approved feed crop. The only country in Asia that has approved and already growing biotech maize is the Philippines where it was first deployed in 2003; Bt maize, herbicide tolerant (HT) maize and the stacked Bt/HT product were grown on approximately ~675,000 hectares in the Philippines in 2012. Biotech maize is likely to be commercialized in China well before Bt rice given Government's priority for biotech maize and the significant increased demand currently being met by increased imports.

- **Bt rice** offers the potential to generate benefits of US$4 billion annually from an average yield increase of up to 8%, and an 80% decrease in insecticides, equivalent to 17 kg per hectare on China's major staple food crop, rice, which occupies 30 million hectares (Huang et al. 2005). It is estimated that 75% of all rice in China is infested with the rice-borer pest, which Bt rice controls. China is the biggest producer of rice in the world (178 million tons of paddy) with 110 million rice-growing households (a total of 440 million people based on 4 per family) who could benefit directly as farmers from this technology, as well as China's 1.3 billion rice consumers. Bt rice will increase productivity of more affordable rice at the very time when China needs new technology to maintain self-sufficiency and increase food production to overcome drought, salinity, pests and other yield constraints associated with climate change and dropping water tables. Crops that use water efficiently and the development of drought tolerant crops is top priority for China. **China needs to increase its rice yield to 7.85 tons per hectare by 2030 when its population will be 1.6 billion** (Chen et al. 2010). **Thus, in 2030, China will need approximately 235 million tonnes of paddy annually, equivalent to one third of global production of approximately 750 million tones.**

In China, it is very important to note that all three approved biotech crops, Bt cotton, Bt phytase maize, and Bt rice were all developed using public resources in Chinese public sector institutions. The significant advantages that these products offer China also apply to other developing countries, particularly in Asia (but also elsewhere in the world), which have similar crop production constraints. Other Asian countries, which could benefit from biotech maize, include India (8 million hectares of maize), Indonesia (3 million hectares), Thailand, Vietnam and Pakistan, all three with approximately 1 million hectares each of maize. Asia grows and consumes 90% of production from the world's 150 million hectares of rice, and Bt rice will have enormous impact in Asia. Not only can Bt rice contribute to an increase in productivity and self-sufficiency but it can also make a substantive contribution to the alleviation of poverty of poor small farmers who represent 50% of the world's poor. Similarly, there are up to 50 million hectares of maize in Asia that could benefit from biotech maize. China's exertion of global leadership in approving biotech rice and maize in 2009 was a positive influence on acceptance and speed of adoption of biotech food and feed crops in Asia, and more generally globally, particularly in developing countries. This approval is exemplary for other countries in pursuit of "self-sufficiency" (optimizing productivity and production of home-grown food) as opposed to "food security" (enough food for all) – the distinction is important and the two goals are not mutually exclusive. China can serve as a model for other developing countries, particularly in Asia, which could have substantive implications for:

- a more timely and efficient approval process for biotech crops in developing countries;
- new modes of South-South technology transfer and sharing, including public/public and public/private sector partnerships;

- more orderly international trade in rice and reduction in probability of recurrence of 2008-type price hikes, which were devastating for the poor; and
- shift of more authority and responsibility to developing countries to optimize "self-sufficiency" and provide more incentive for their involvement to deliver their share of the 2015 Millennium Development Goals.

Bt Cotton Adoption

Like the USA, Argentina and Canada, China is a member of the group of six "founder biotech crop countries", having first commercialized biotech crops in 1996, the first year of global commercialization. The national area planted to cotton in China in 2012, at 4.9 million hectares was significantly lower than that planted in 2011 at 5.5 million hectares, but the adoption rate increased to 80% in 2012 thus offsetting the decrease in total area of cotton. The area planted to Bt cotton in 2012, 3.946 million hectares was approximately the same as 2011 when adoption rate was only 71.5%. The size of farms in China is very small. In a recent survey of cotton farms, the average size of farm, as determined by the area of cultivable land, was 0.8 hectare and the average size of a cotton holding was approximately 0.5 to 0.6 hectare. An estimated 7.2 million small and resource-poor farmers grew 3.946 million hectares of Bt cotton in China in 2012. An important paper in Science (Wu et al. 2008) suggested that the potential number of small farmers actually benefiting indirectly from Bt cotton in China might be as high as 10 million more. It is noteworthy that a paper by Hutchinson (2010) based on studies in the USA draws similar conclusions to Wu et al. (2008) – indeed it reports that the indirect benefits for conventional crops grown in the same area where biotech crops are deployed, are actually greater than the direct benefits from biotech crops. For more details see the Chapter on the USA in this Brief.

Following the extensive planting of Bt cotton in six northern provinces of Hebei, Shandong, Jiangsu, Shanxi, Henan and Anhui in China, during the period 1997 to 2006, Wu et al. (2008) reported that cotton bollworm populations decreased markedly by up to 10-fold (approximately 90% from around 3,000 in 1997 to 300 in 2006) in other crops that also host the cotton bollworm – these include maize, peanut, sesame, legumes, wheat, sorghum, vegetables and melons. Whereas cotton occupies only about 3 million hectares and farmed by an estimated 5 million farmers in the six northern provinces in China, host crops of cotton bollworm occupy 7 times the area at 22 million hectares and are farmed by more than 10 million farmers receiving indirect benefits from Bt cotton – i.e. farmers deriving indirect benefits from Bt cotton number twice the number of Bt cotton farmers (5 million) that derive direct benefits from Bt cotton. Thus importantly, his study concludes that Bt cotton not only provides control for the damaging cotton bollworm on cotton but results in the suppression of cotton bollworm on several other important host crops that occupy more than seven times the area of Bt cotton. The dramatic reduction by 90% in the level of cotton bollworm in host crops other than cotton has implications for insecticide savings, which may translate to a significant decrease in the need for insecticide sprays on these host crops, other than cotton, cultivated by approximately 10 million farmers. This important finding may mean that the number of farmers that benefit directly and indirectly from Bt cotton in northern China, may number an additional 10 million, compared with the 5 million that benefit from Bt cotton directly in the six northern provinces of China. Thus, past estimates of the benefits associated with Bt cotton in China in terms of the number of beneficiary farmers, and economic, agronomic and environmental benefits may have been grossly underestimated because the benefits to farmers cultivating crops other than cotton that host cotton bollworm were not known and have not been considered or included in impact studies of Bt cotton.

Coincidentally, as a result of the decrease in use of broad spectrum sprays for the control of cotton bollworm in cotton in northern China, mirids, which were previously a secondary insect pest of relatively low economic importance have not surprisingly become relatively more important. This demonstrates the need and importance for a broad integrated pest management strategy for the control of insect pets featuring both biotechnology and other means of control.

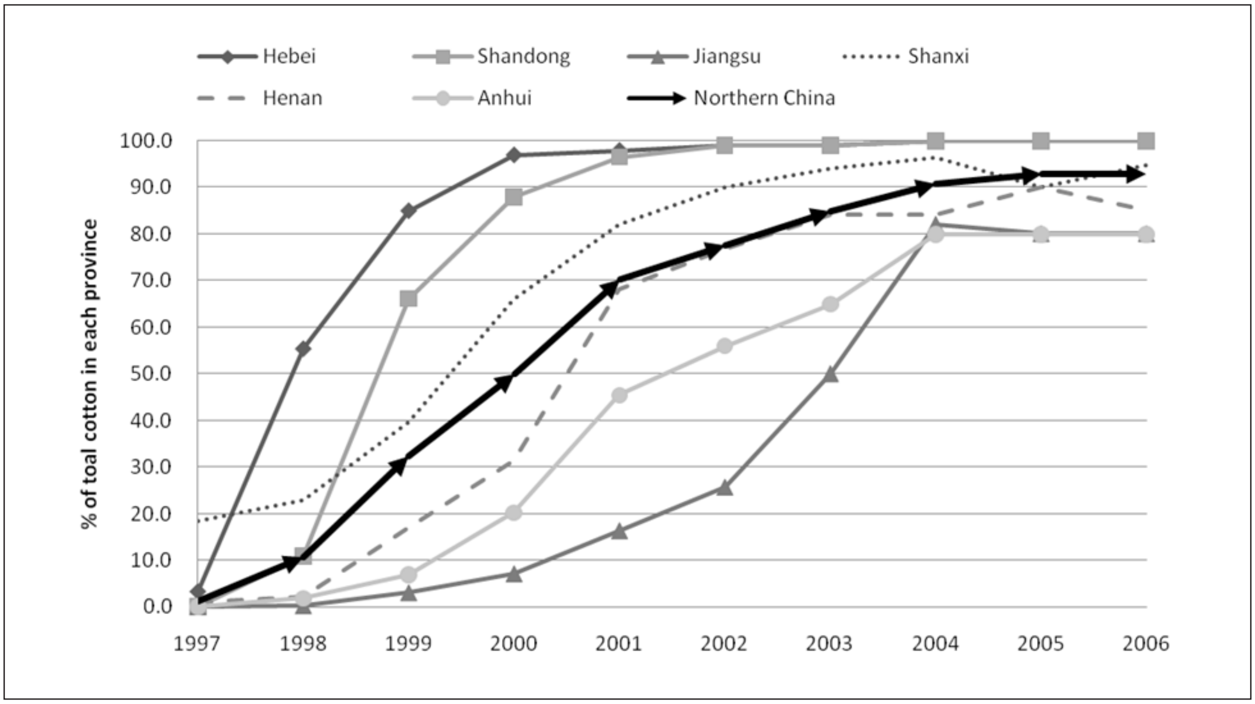
Entomologists A. M. Shelton Ph.D., Mao Chen Ph.D. and Jianzhou Zhao, Ph.D., all affiliated with Cornell University in the US (Personal Communication, 2010) offered the following important commentary on the success of Bt cotton in China and a proposed strategy for controlling the increasingly important mirids, and other pests, not controlled by Bt cotton.

> "The cotton bollworm (*Helicoverpa armigera*) and pink bollworm (*Pectinophora gossypiella*) are the most devastating pests on cotton in China and are the key pests that Chinese cotton farmers have traditionally had difficulty in controlling, even with frequent insecticide spray programs. Bt cotton has changed this situation. The high adoption rate of Bt cotton in China has resulted in effective suppression of both species on cotton and also regional suppression of the polyphagous *H. armigera* on a number of other crops (e.g. peanuts, soybean and vegetables). This situation has resulted in dramatic reductions in the use of traditional, broad-spectrum insecticides which, in turn, have led to decreased environmental harm and fewer farmer poisonings. However, since Bt cotton only controls the caterpillar pests, in some cases other arthropod populations have increased. This includes cotton aphids (*Aphis gossypii, A. atrata, A. medicaginis,* and *Acyrthosiphon gossypii*), mirids (*Adelphocoris suturalis, A. lineolatus, A. fasciaticollis, Lygus lucorum,* and *L. pratensis*), spider mites (*Tetranychus cinnabarinus, T. truncates, T. turkestani,* and *T. dunhuangensis*), thrips (*Frankliniella intonsa, Thrips tabaci,* and *T. flavus*), and whiteflies (*Bemisia argentifolii* and *B. tabaci*).
>
> Management programs for the insect complex not affected by Bt proteins need to be put into place and these include the use of some systemic insecticides which are far safer on the environment and natural enemies. From the pest management standpoint, conservation of such natural enemies, through the use of Bt plants and selective insecticides is key for managing the entire pest complex of cotton and is part of an overall integrated pest management (IPM)

> approach needed for sustainable cotton production. Such comprehensive IPM programs have proven effective for key and secondary arthropod pests in the US where Bt cotton adoption continues to climb and reached ~90% of all upland cotton production in the US in 2011. Chinese scientists are exploring strategies so that they can also obtain similar comprehensive IPM programs."

The field data from China's Ministry of Agriculture used in the same study by Wu et al. (2008) also clearly demonstrated the unusually high and rapid adoption of Bt cotton in each of the six provinces of northern China during the period 1997 to 2006 (Figure 25). It is noteworthy that adoption of Bt cotton was fastest in the two provinces of Hebei and Shangdong reaching over 95% in the short span of 5 years and 100% in 8 years. The adoption rates in the provinces of Jiangsu, Shanxi, Henan and Anhui were almost as fast, reaching 80 to 90% in 8 years or less (Figure 25). In northern China, as a region, more than 66% adoption of Bt cotton was reached in only 5 years. These adoption rates are remarkably high by any standard and reflect the vote of confidence and trust of farmers in Bt cotton, which has delivered multiple and significant economic, agronomic and socio-economic benefits consistently from 1997, the first year of commercialization, to the present.

Figure 25. Adoption of Bt Cotton in Each Province of Northern China, as Percentage, 1997 to 2006



Source: Wu et al. 2008, Data in Annex from China's Ministry of Agriculture.

One of the important indicators that reflect farmers' confidence in any new technology, including Bt cotton, is the extent to which farmers repeat the planting of Bt cotton in the following season. In 2006 and 2007, of 240 cotton growing households surveyed in 12 villages in three provinces – Hebei, Henan and Shandong, by the Center for Chinese Agricultural Policy (CCAP) of the Chinese Academy of Sciences (CAS), it is notable that every single family that reported growing Bt cotton in 2006 also elected to grow Bt cotton in 2007. Thus, the repeat index for farmers growing Bt cotton in 2006 and 2007 in three provinces in China was 100%. Interestingly, of the 240 farmers surveyed, a few farmers in one village also grew one variety of non-Bt cotton in 2006 that they also grew in 2007. This reflects the fact that farmers invariably want to compare the performance of old and improved technologies side-by-side in their own fields. The same happened during the introduction of hybrid maize in the corn belt in the USA – farmers planted the best performing varieties next to the new hybrids until they were satisfied that hybrids consistently out-performed their old varieties, and it took several years before hybrid maize was fully adopted.

Adoption of Virus Resistant Papaya

In September 2006, China's National Biosafety Committee recommended for commercialization a locally developed biotech papaya resistant to papaya ring spot virus (PRSV) (Table 19). The technology features the viral replicase gene and was developed by South China Agricultural University; the papaya biotech variety is highly resistant to all the local strains of PRSV. This approval and eventual commercialization in China was a significant development in that papaya is a fruit/food crop, which is widely consumed as fresh fruit throughout the country. The main province for papaya production in China is the province of Guangdong where 95% of the papaya is now biotech papaya, resistant to the lethal papaya ring spot virus (PRSV) disease. In 2012, virus resistant papaya was also grown

Table 19. Approval of Biotech Crops in China

Crop	Year of Approval
Cotton	1997
Petunia	1997
Tomato	1998
Sweet Pepper	1998
Poplar Trees	2003
Papaya	2006
Rice (Bt)	2009 (27 November, biosafety approval)
Maize (Phytase)	2009 (27 November, biosafety approval)

Source: Compiled by Clive James, 2011.

for the first time in Hainan Island where 40% of 5,000 hectares of biotech papaya was grown for a total of 6,275 hectares in China. The adoption rate in 2012 in Guangdong was estimated at 95%, approximately the same as 2011 and 2010. The adoption of virus-resistant biotech papaya in China as a country in 2012 increased in absolute hectarage to a record 6,275 hectares, an 18% increase over the 5,305 hectares in 2011 (Personal Communication, Prof Li, South China Agricultural University). The percentage adoption of biotech papaya in Guangdong was 95% in 2012 and historically has consistently increased annually from 70% adoption, (equivalent to 3,550 hectares) in 2007 when it was first commercialized, to 88% in 2008, and 90% in 2009.

Insect Resistant Poplar

Biotechnology has also been applied to trees in China and Bt poplars (*Populus nigra*) have been approved for commercialization. The first Bt poplars were developed and commercialized in 2003 by the Research Institute of Forestry in Beijing, which is part of the Chinese Academy of Forestry. It is estimated that by 2015, China will need 330-340 million cubic meters of timber, of which approximately half, or 140-150 million cubic meters, will have to be produced in China, with the balance imported. In order to meet this challenging goal, the development of improved tree plantations in China was accelerated. Some fast-growing trees, such as poplar, eucalyptus, larch, and Chinese fir, were carefully selected and widely planted in China. During the past 20 years, a total of 7.04 million hectares of selected poplar clones were planted in China for commercial production; this represents a significant 19% of total tree plantations in China. However, it was observed that these mono-clonal plantations were susceptible to insect pests which caused severe infestations resulting in significant damage, estimated at millions of US dollars annually.

In order to develop poplars that were more tolerant to insect attack, GM/biotech poplars were developed in China. More specifically, *Populus nigra* clones 12, 172 and 153, were developed with *cry1Aa* and a hybrid white poplar, clone 741, was also transformed with a fusion product of *cry1Aa* and API coding for a proteinase inhibitor from *Sagittaria sagittifolia*. Six hectares of transgenic poplars were harvested in Manasi Plain Forest Station, Xinjiang Uygur Autonomous Region, but no new plantations were established in 2011, except nearly 7 hectares of seedlings of the commercialized transgenic *P. nigra* transformed with *cry1Aa* were grown. Thus, with the harvesting of 6 hectares from the 490 hectares and the planting of an additional 7 hectares, that results in a net gain of 1 hectare for a total of 491 hectares of mature Bt poplars in China in 2012.

Under rigorous performance testing, the Bt poplar clones have exhibited a high level of resistance to leaf pests, resulting in a substantial 90% reduction in leaf damage. The two clones were first commercialized in 2003 in Northern China, and by 2011, they occupied 490 hectares compared with 453 hectares in 2010, (although the 30 hectare plantation in Huairou, Beijing was felled in 2011), 447 hectares in 2009 and 400 hectares in 2008. The transgenic poplar plantations have effectively inhibited the fast-spread of target insect pests and have significantly reduced the number of insecticide applications required. The performance of the Bt black poplar plantations is significantly better than the clones deployed locally. The availability of commercial Bt poplar plantations has made it possible to empirically assess gene flow via pollen and seeds, and also for assessing the impact of Bt poplar on the insect community when intercropping with Bt cotton. The transgenic *Populus nigra* has also been used for hybridizing with non-transgenic *P. deltoides* to generate an insect resistant source in a breeding program designed to generate new hybrid clones. There are now 3 transgenic poplar lines approved for environmental release in China, and another 5 have been deployed in small-scale field trials. Transformation of poplar with diverse traits such as tolerance to freezing, control of flowering and modification of wood specifications with improved pulping qualities and more efficient saccharification (conversion of lignocellulose to sugar) are in progress.

About 91% of the 490 hectares in 2011 were Bt *Populus nigra* clones, and the balance of 9% was clone 741 featuring *cry1Aa* and API. A new clone under development, a hybrid white poplar clone 84K transformed with the *Bt886Cry3Aa* resistance gene, has already undergone testing in nurseries and the preliminary results are promising. Clone 84K with *Bt886Cry3Aa* is tolerant to the economically important Asian longhorn beetle, which attacks the trunks of poplars and can cause significant damage. Comparisons between Bt poplar and non-Bt checks, confirm that Bt poplars require no insect pest control in the first 6 years, compared with the checks, which required 2 to 3 insecticide sprays (Lu M-Z, 2010, Personal Communication). This is consistent with experimental data (Table 20) confirming that Bt clones performed better and grew faster than their conventional counterparts. For example, at 10 years old, the tree trunk diameter was 28.2 cms for the Bt clone at the Beijing location versus 25.4 cms for the non- Bt clone “Zhonglin 46”. Similarly, the Bt clone at the Hebei location had 20.9 cm diameter after 8 years, versus 18.6 cms compared to the non-Bt clone “*P. deltoides* cv Chuangxin”.

As of the end of 2010, 33 field trials had been approved and implemented featuring tolerance to insects, diseases, drought, and wood quality traits. Biotech/transgenic *Populus tomentosa* with antisense CCoAOMOT (coding for a key enzyme involved in lignin monomer) is currently being tested under an environmental release permit, prior to being submitted for commercialization approval. In December 2011, field trials of transgenic triploid *Populus tomentosa* cl. “BL73”, hybrid white poplar “741” and *P. euramericana* cv. ‘Neva’ were approved by the State Forestry Administration. This included 5 “BL73” transgenic lines with double Bt genes (*cry3A, cry1Ac*), 7 “741” lines with triple insect resistance genes (*cry3A, cry1Ac, API*) and 4 ‘Neva’ lines with double *Bt* genes (*cry3A, cry1Ac*). Also in 2011, 6 “741” transgenic lines with *Bt* (*cry3A*) were approved for release into the environment to conduct a pilot production test. The one hectare areas for the tests are located in Yixian, Hebei and Ninghe, Tianjin. These tests allowed the investigation of the dynamics of *Bt* toxins temporally and spatially, as well as the insect tolerance of the transgenic poplar plantations. A mortality of more than 90% of the larvae of *Pynrrhalta aenescens* and inhibition of growth by 50% were observed in the plantations.

Table 20. Comparisons Between Performance of Bt Poplar Clones and non-Bt Clones in China in the Period 2001 to 2011

Location	Clone	Trunk Diam, cms.	Tree Age Years	Area (hectares)
Huairou, Beijing	Bt Poplar *P. nigra*	28.2	10	30
Huairou, Beijing	Non Bt *P. euramerican* Zhonglin 46	25.4	10	45
Renqiu, Hebei	Bt Poplar *P. nigra*	20.8	8	22
Renqiu, Hebei	Non-Bt *P. deltoides* cv Chuangxin	18.6	8	30

Source: Lu M-Z, 2011, Personal Communication.

Chinese Private Sector Seed Companies and Public-Private Sector Partnerships

One of the noteworthy features of crop biotechnology in China is the emergence of private seed companies, which conduct R&D in crop biotechnology, and develop and distribute both conventional and biotech hybrid seed. One such company is Origin Agritech Limited, which is based in Beijing, and trades on the NASDAQ in the US as SEED – it is China's lead, vertically integrated biotech seed company. It was founded in 1997 and conducts R&D to produce conventional and biotech hybrid seed, of which conventional maize is currently the principal commercial crop. Origin operates in China and South East Asia and has a large network of 3,800 primary distributors and 65,000 secondary distributors. Origin prepares financial statements according to the US GAAP accounting procedures. For the third quarter, 1 April to 30 June 2010, revenues were approximately US$68 million with a gross profit of US$28 million (Business Wire, 30 August 2010).

On 22 September 2010, Origin announced that it had reached an agreement with the Institute of Plant Protection of the Chinese Academy of Agricultural Sciences (CAAS) for the worldwide exclusive rights of the Bt gene developed by the Academy; Origin already had the rights to use the Bt gene in China. Under the new agreement Origin has the right to sublicense the Bt gene and/or to improve its performance (Business Wire, 22 September 2010).

Earlier, Origin had also acquired the rights to phytase maize from CAAS and this product was approved for biosafety by China on 27 November 2009 (Origin Agritech, 2009). The potential phytase maize market worldwide is estimated at US$500 million per year, of which US$200 million is in China alone. To put this into context, the current conventional maize seed market in China is estimated to be worth over US$1 billion per year – this compares with US$12 billion for the hybrid maize seed market annually in the US. Phytase maize is expected to be the first biotech maize to be commercialized in China by Origin followed by glyphosate tolerant maize, which is currently in Phase 3 of environmental field tests, and then Bt maize. Origin has already submitted Bt maize for phase 3 field trials and stacking all three genes coding for phytase, glyphosate tolerance and Bt, is a future option. Many maize growing countries have already successfully implemented the option of stacking genes with herbicide tolerance and Bt insect resistance but China is likely to be the first to deploy phytase maize; this is a very important product for China given the importance of pork as a meat, in the country which has over 500 million swine, equivalent to about half of the global swine herd. Phytase maize will also be beneficial to the Chinese US$13 billion poultry industry, the largest in the world, and will coincidentally result in less ecological pollution by phosphates of ecological zones and waterways.

There are a growing number of collaborative initiatives between Chinese institutions and foreign companies and institutions. For example, the China National Seed Group (China Seed) and Monsanto have agreed to extend their respective investments in their joint venture company, CNSGC-DEKALB Seed Company Ltd. (CNDK) – the agreement is pending approval by the Chinese Government. CNDK was formed in 2001 to market maize hybrids in China, the second largest market for maize hybrids in the world, after the USA. In November 2009, Monsanto announced the establishment of its Biotechnology Research Center in Zhongguancun, Beijing that will allow the company to strengthen its links with Chinese Research Institutions in plant biotechnology and genomics. In November 2008, Bayer Crop Science signed an MOU with the Chinese Academy of Agricultural Sciences (CAAS) for joint development and global marketing of new agricultural products which will strengthen and expand the seed and traits business of both parties in China.

The decision by China on 5 September 2008 to approve for import the RR2Yield™ soybean was a major development with significant implications (McWilliams, 2008). China, the most populous country in the world is also the largest consumer of edible soybean in the world. China spent US$4 billion importing US soybean in 2007 which accounted for 38% of all US soybean exports. Prior to the Chinese approval, RR2Yield™ soybean had already been approved as safe for food, feed in the USA, Canada, Mexico, Taiwan, Japan, the Philippines, Australia and New Zealand which collectively import 30% of all US soy exports. The approval from China means that over two thirds (68%) of the US soybean export markets have already been cleared with China representing more than half (38% out of 68%).

Support for Biotech Crops in China

It is evident that after the 27 November 2009 biosafety approvals of both biotech rice and maize, that Chinese policymakers view agricultural biotechnology as a strategic element for increasing productivity and self-sufficiency, improving national food security and ensuring competitiveness in the international market place. There is no doubt that China is now one of the world leaders in crop biotechnology since Chinese policymakers have concluded that there are unacceptable risks of being dependent on imported technologies for food security. In addition to cotton which is already deployed and the approved Bt rice and phytase maize, China has an impressive portfolio of a dozen other biotech crops being field-tested, including wheat, potato, tomato, soybean, cabbage, peanut, melon, papaya, sweet pepper, chili, rapeseed, and tobacco.

It is instructive to trace the increasing political will, support and confidence in biotech crops prior to the 27 November 2009 approval of Bt rice and phytase maize. In June 2008, **Chinese Premier Wen Jiabao** addressed the Chinese Academy of Science and stated that, ***"To solve the food problem, we have to rely on big science and technology measures, rely on biotechnology, rely on GM."*** This was a remarkably strong statement of support for biotech crops from China's cabinet and Premier Wen Jiabao, who urged authorities to ***"waste no time to implement the program and understand the urgency and importance of the program."*** In July 2008, Premier Wen Jiabao, in his capacity as Chairman of the State Council, announced that the cabinet had approved a significant increase in budget for GM crops of 4 to 5 billion Yuan, equivalent to US$584 million to US$730 million in the coming years. As of 2006, China had approved 211 field trials for a total of 20 crops.

Elsewhere in Asia, outside China, there are also significant R&D investments on biotech rice featuring agronomic and quality traits. For example, a team at the University of Tokyo, Japan has developed biotech rice that can tolerate iron deficiency, which is a very prevalent constraint in the rice growing countries of Asia (Takanori et al. 2008). Deployment of a rice, tolerant to iron deficiency, is one of many biotechnology applications, including pest and disease resistance and pro-Vitamin A enhanced Golden Rice (expected to be available in Asia in 2013) that could contribute to higher productivity and improved nutritional quality of rice. Rice is not only the most important food crop in the world but is also the most important food crop of the poor in the world. This is particularly true in Asia where 90% of the world's rice is produced and consumed and where rice has a very important cultural role. In Asia, rice is the staple of 600 million extremely poor rural people, mostly subsistence farmers and the rural landless who are completely dependent on agriculture for their livelihood. Hence, biotech rice with improved attributes can make an enormous contribution to the alleviation of poverty and hunger in Asia but also in Latin America and Africa where rice is important, particularly for the poorer in rural communities.

China is very much cognizant of the essential need for biosafety management in order to ensure protection of the environment and consumers, and this was the major consideration in the biosafety approval of Bt rice in November 2009. Given the paramount importance of rice as the principal food crop in China, approximately 20% of the government's investment in crop biotechnology has been devoted to rice. This was equivalent to an annual investment of US$24 million at official exchange rates, or US$120 million per year at a purchasing power parity rate of five, which undoubtedly makes China's investment in rice biotechnology, by far, the largest in the world. Three insect resistant hybrid rice varieties, two featuring the Bt gene and the other with the *CpTi trypsin* gene, entered pre-production field trials in 2001, plus a rice variety carrying the *Xa21* gene that confers resistance to the important bacterial blight disease of rice. Annual and extensive large-scale pre-production trials of these new biotech hybrids of rice, starting in 2001, confirmed yield increases of approximately 2 to 6%, plus a saving of 17 kg per hectare in pesticides, with positive health implications, along with a labor saving of 8 days per hectare, resulting in an overall increase in net income per hectare of US$80 to US$100. It is projected that with full adoption, the new biotech rice hybrids could result in a national benefit to China of US$4 billion; insect borers, which can be controlled by Bt, are prevalent on up to 75% of approximately 30 million hectares of rice in China (Jikun Huang, 2009. Personal Communication).

Whereas ISAAA has no knowledge of biotech rice being approved in any other country except China, the previous administration in Iran did temporarily officially release a Bt rice in 2004 to coincide with the celebration of the International Rice Year. The biotech rice, a high quality rice named *"Tarom molaii"*, was estimated to have been cultivated on 2,000 hectares in 2004 and was grown successfully on 4,000 hectares by more than 500 farmers in 2005, because it yielded significantly more than its conventional counterpart. The National Biosafety Council of Iran is now apparently reviewing the dossier on biotech rice as part of the process of approving and commercialization of rice in Iran.

With the approval of biotech rice in November 2009, this leaves wheat, as the only one of the three major world staples: maize, rice and wheat, to be denied the significant advantages offered by biotechnology. The adoption of biotech rice and maize in Asia will, in due course, greatly facilitate and expedite the approval and adoption of biotech wheat. The first biotech wheat to be approved in China in about 7 years may be virus resistant (yellow mosaic virus), which is being field tested. A "sprout tolerant" wheat is also being developed in China. Wheat with improved resistance to *Fusarium* and thus lower levels of mycotoxin is also under development as well as quality traits, and for the longer term, the more challenging task of improved drought resistance.

The near-term food and feed needs of China, and more broadly Asia, are not limited to the major crop rice, but also apply to maize for feed, and also, more and better quality wheat for food. China's priority-trait needs include disease and insect resistance, herbicide tolerance as well as quality traits. China has an impressive stable of its own home-grown biotech crops with various traits which can be complemented with products developed by the public and private sectors from the global crop biotech market. China has estimated the potential benefits from both biotech cotton and rice at US$5 billion per year and can complement these gains by applying biotechnology to the other staples of maize and wheat, and up to a dozen other crops in the near, medium and long term.

China considers food safety and self-sufficiency top priorities and importantly, as basic human rights. China is committed to transform agriculture from a traditional to a modern agriculture with high priority assigned to crop biotechnology. China has consistently maintained a grain self-sufficiency of 95% or more in recent years, and has made a significant contribution to the alleviation of poverty (People's Daily, 2009). In 2008, total grain production in China reached 525 million tons, compared with only 113 million tons in 1949. In 2007, per capita rural income was 4,140 Yuan (US$608), five times what it was in 1978. The number of rural poor has declined from 250 million in 1978 to 15 million today. China, with the exception of India, is one of very few developing countries which has increased investments in agriculture significantly and as a result reaped handsome benefits. The Chinese Government increased its investments in agriculture by 30% in 2007, by 38% in 2008 and by another 20% in 2009. Maize yield increased from 1.18 tons in 1961 to 5.61 tons per hectare in 2007, rice from 2.0 to 6.3 tons and wheat from 0.6 tons to 4.6 tons per hectare, in the same period. The new target for the Chinese Government is to increase total grain production to 540 million tons by 2020 and to double Chinese farmers' 2008 income by 2020 (Xinhua, 2009). These are challenging and formidable targets but past experience and perseverance in successfully attaining equally formidable goals would indicate that for China, they are feasible. The major challenge is to increase crop productivity significantly in the face of water scarcity, loss of fertile land and slowing agricultural productivity constrained by the law of diminishing returns, slowing gains from successful past technologies. China is currently setting up 20 agricultural technology demonstration centers in the developing world and plans to double the number of Chinese agricultural experts assigned to agricultural development projects in Asia, Africa and Latin America.

Benefits from Biotech Crops in China

Bt cotton – In 2012, Bt cotton was planted by 7.2 million small and resource-poor farmers on ~4 million hectares, which is 80% of the ~5 million hectares of all cotton planted in China in 2012. Based on studies conducted by the Center for Chinese Agricultural Policy (CCAP), it was concluded that, on average at the farm level, Bt cotton increases yield by 10%, reduces insecticide use by 60%, with positive implications for both the environment and the farmers' health, and generates a substantial US$220 per hectare increase in income which makes a significant contribution to their livelihood as the income of many cotton farmers can be as low as around US$1 per day (Jikun

Huang, 2008, Personal Communication). At the national level, it is estimated that increased income from Bt cotton was approximately US$1 billion per year in 2011. **It is estimated that China has enhanced its farm income from biotech cotton by US$13 billion in the period 1997 to 2011 and by US$2.2 billion in 2011 alone (Brookes and Barfoot, 2013, Forthcoming).**

Biotech rice – The biotech hybrid rice is resistant to specific pests (insect borers). The product, based on CCAP's study, increased yield by up to 8%, reduced insecticide application by nearly 80% or 17 kg per hectare. At a national level, it is projected that biotech rice could deliver benefits of the order of US$4 billion per year in the future, plus environmental benefits that will contribute to a more sustainable agriculture and the alleviation of poverty for small and resource-poor farmers (Jikun Huang, Personal Communication).

Political Support for Biotech crops in China

The President of China Hu Jintao emphasized that ***"Science and technology are the basis of building an innovative country, speeding up the transformation of economic development. China should vigorously develop modern science and technology by developing high quality, efficient, and safe agriculture and related bio-industries; and ensuring security of food and major agricultural products."*** These thoughts were shared by the Chinese President Hu Jintao during the 15th Academician Conference of the Chinese Academy of Sciences. At the 10th Academician Conference of the Chinese Academy of Engineering on June 7, 2010 in Beijing, the President also stressed that ***"China will fully develop advanced breeding techniques to improve the quality, yield and disease resistance of agricultural products. He said that this will assure sustainable development and competitiveness of the nation's agricultural sector"*** (Hu, 2010).

Chinese Vice Minister for Agriculture Zhang Taolin called for the need to promote the development of the seed industry in China. Zhang, speaking at the first China Agricultural Scientific and Technological Innovation Forum, emphasized the need to speed up technological innovations in the seed industry. Zhang also called authorities to ***"scale up management of seed industry, revise and improve relevant regulations and rules, improve examination criteria of varieties and threshold of market access, and standardize the examination, production and operation of genetically modified organisms (GMOs)"*** (Zhang, 2010).

Dr. Dafang Huang, former Director of the Biotechnology Research Institute under the Chinese Academy of Agricultural Sciences (CAAS), in an interview by the Xinhua News Agency said that, ***"We are technically advantageous in hybrid rice planting. The genetically modified technology could ensure China's superiority in food production."*** Supporting Dr. Huang's statement was **Dr. Wu Yongning**, a scientist at the Chinese Center for Disease Control and Prevention, ***"I am***

not ruling out all possible risks, but those risks of genetically-modified food are no greater than that of traditional ones, given the heavy use of pesticide in growing traditional food" (Huang, 2010).

At the 43rd Shanghai Academician Salon held in the Hall of Science, Shanghai, China on April 13, 2010, **Prof. Lin Hongxuan, Academician of Chinese Academy of Sciences, Chinese Academy of Engineering**, discussed biotechnology applications for breeding of new crop varieties with desirable traits and its role in modern agriculture production and said that ***"This reform in bio-breeding is irreversible, and we should face it actively,"*** said Prof. Lin. ***"The bio-breeding (biotechnology) industry should be promoted on the basis of scientific evaluation through multi-channel and multi-level public education"*** (Lin, 2010).

Deputy Minister Chen Xiaohua of China's Ministry of Agriculture confirmed that ***"China will continue its development of GM crops because this is an important strategic move to the whole nation"*** (Global Times, 30 September 2011). Chen reassured observers that China will develop GM technologies in strict accordance with relevant regulations and ensure the safety of GM products adding that ***"the Ministry is drawing up plans to expand corn production to meet increasing domestic demand."***

Brief Chronological Overview of crop biotech related events in China in 2012 reported in ISAAA's weekly Crop Biotech Update (CBU), where original reference is provided:

1. Following the success in the release of the first draft of the cassava genome from a CIAT accession in 2009, a new large scale collaborative project between the International Center for Tropical Agriculture (CIAT) and Beijing Genomic Institute (BGI) Shenzhen, China was established to sequence 5,000 cassava genotypes, including landraces, improved varieties, experimental populations and related wild species of the crop (Crop Biotech Update, 9 December 2012).

2. Researchers from Cotton Research Institute, Chinese Academy of Agricultural Sciences (CAAS) successfully developed GM cotton which has high quality fiber and develops big bolls, a breakthrough in the second generation GM cotton research in China (Crop Biotech Update, 13 April 2012).

3. The Nitrogen Use Efficiency (NUE) Technology of Arcadia Biosciences Inc. has been issued a key patent by the State Intellectual Property Office of China for a nitrogen use efficiency technology will allow farmers to use significantly less nitrogen fertilizer on their crops and

maintain high yields as demonstrated in country trials in important grain crops such as rice and wheat (Crop Biotech Update, 4 May 2012).

4. The international research team led by scientists from the Chinese Academy of Agricultural Sciences (CAAS) and Beijing Genomics Institute (BGI) have completed the genome sequence and analysis of a diploid cotton *Gossypium raimondii*, providing important resource for the study and genetic improvement of cotton quality and understanding of the genetic characteristics and evolutionary mechanism of the crop (Crop Biotech Update, 5 September 2012).

Farmer Experience

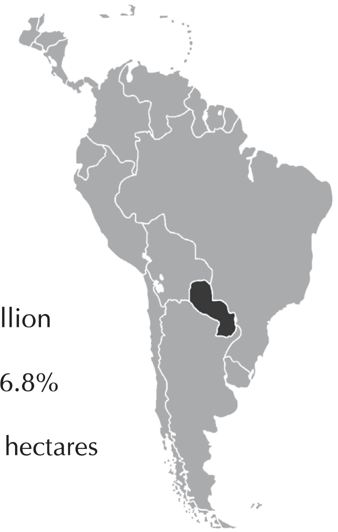
Niu Qingjun is a typical Chinese cotton farmer in Shandong province in China, one of the largest cotton growing provinces in the country. Niu is 42 years old, married with two children and 80% of the family income comes from cotton, which represents the livelihood of the whole family. Niu has been growing Bt cotton since 1998. The total size of his farm is 0.61 hectare and cotton is the only crop that he grows on his farm. Niu's experience with Bt cotton is captured in the following comments. ***"We could not even plant cotton if there is no insect resistant cotton (Bt cotton). We could not control bollworm infestation before planting insect resistant cotton, even if spraying 40 times insecticide in 1997."*** Niu harvested 2,680 kg of seed cotton in 2007; given that the price of seed cotton is 6.8 RMB/kg, he would approximately make a profit of 14,000 RMB or US$1,886 (not including labor inputs). Niu only sprayed insecticide 12 times in 2007, approximately half the number of sprays he used on conventional cotton prior to the introduction of Bt cotton (Qingjun, 2007).

Before 1997, **Zu Maotang** was one of the cotton farmers across China who were having problems with bollworms. He was using 13 to 15 pesticide sprays per mu (1 mu = 1/15 hectare) and worms were already becoming resistant to the insecticide. He learned about experiments on Bt cotton from Dr. Guo Sandui at the Chinese Academy of Sciences, and a partnership between the farmer and scientist took place. Mr. Zu had a chance to save his livelihood, while Dr. Guo had Mr. Zu's farm for crop testing. Mr. Zu became the first biotech cotton farmer in China, and since then he has enjoyed more than a 10-fold increase in yield (180-190 kg per ha). He has improved the financial status of the family and proudly purchased a family flat in a nearby city. He now shares his expertise through an agricultural association he set up to help farmers in his community. As he says, ***"Deng Xiaoping gave us policies for prosperity – and ag-scientists gave us the tools to achieve it"*** (Maotang, 2010).

PARAGUAY

Paraguay has successfully grown RR®soybean for nine years since 2004. In October 2011, Paraguay approved a second biotech crop, Bt (MON 531) cotton for commercial production. The country approved biotech maize for the first time in September 24, 2012, that includes events MON810, Bt11, TC1507 and MON89034 x MON88017. In 2012, Paraguay grew a total hectarage of 4.2 million hectares of soybean, cotton and maize, of which a record 3.4 million hectares (~80% adoption) were biotech. Of the 3.1 million hectares of soybean ~95% or 2.9 million hectares were biotech. Of 1.1 million hectares of maize estimated for 2012/2013, taking into account the incorporation of the new authorizations, 40% were biotech and similarly, 45% of the 100,000 hectares of cotton were biotech. Also, as an exemption for this year, the cotton events MON 531 x MON1445 (BT x RR) and MON 1445 were authorized. Economic gains over the period 2004 to 2011 is estimated at US$732 million and the benefits for 2011 alone at US$82.8 million.

PARAGUAY



Population: 6.3 million

GDP: US$14 billion

GDP per Capita: US$2,130

Agriculture as % GDP: 19%

Agricultural GDP: US$2.7 billion

% employed in agriculture: 26.8%

Arable Land (AL): 4.3 million hectares

Ratio of AL/Population*: 3.0

Major crops:
- Cassava
- Maize
- Soybean
- Wheat
- Sugarcane

Commercialized Biotech Crop:
- HT Soybean
- Bt/HT Maize
- Bt/HT Cotton

Total area under biotech crops and (%) increase in 2012:
3.4 Million Hectares (+21%)

Farm income gain from biotech, 2004-2011: US$732 million

*Ratio: % global arable land / % global population

Paraguay is the world's number four exporter of soybeans. It grew biotech soybean unofficially for several years before it approved four herbicide tolerant soybean varieties in 2004. In 2012, Paraguay was expected to grow a total of 3.1 million hectares of soybean of which a record 2.9 million hectares (approximately 95% adoption) was biotech herbicide tolerant soybean; this compares with 2.6 million hectares of biotech soybean in 2010 out of a total of 2.7 million hectares. The increase in 2012 was mainly due to more total plantings of soybean. Paraguay is one of the 11 countries that have successfully grown biotech soybeans; the eleven countries, listed in order of biotech soybean hectarage are the USA, Argentina, Brazil, Paraguay, Canada, Bolivia, Uruguay, South Africa, Mexico, Chile and Costa Rica.

In October 2011, Paraguay approved its second biotech crop, Bt cotton for commercial production. Four biotech maize events were officially approved in 2012 (Table 21). Its neighboring countries Argentina and Brazil have been growing biotech maize successfully for many years. In 2012, Paraguay was expected to grow a total of approximately 1.1 million hectares of maize of which 40% or 440,000 was biotech. There is benefit for utilizing biotech maize for economic, environmental and social benefits and its neighbors Argentina and Brazil are already benefiting from Bt and herbicide tolerant maize, as well as the stacked product. Paraguay was expected to grow 100,000 hectares of cotton in 2012, of which 45% or 45,000 hectares are biotech. Paraguay will benefit from biotech cotton also successfully grown in the neighboring countries of Argentina and Brazil.

Benefits from Biotech Crops in Paraguay

Paraguay is estimated to have enhanced farm income from biotech soybean by US$732 million in the period 2004 to 2011 and the benefits for 2011 alone is estimated at US$82.8 million (Brookes and Barfoot, 2013, Forthcoming).

Table 21. Commercial Approvals for Planting, Food and Feed in Paraguay, 2004 to 2012

Crop	Trait	Event	Year
Soybean	Herbicide tolerance (HT)	40-3-2	2004
Cotton	Insect tolerance (IR)	MON 531	2011
Maize	IR	MON 810	2012
	IR	BT11	2012
	IR, HT	TC1507	2012
	IR x HT	MON 89034 x MON 88017	2012
Cotton	IR x HT	MON 531 x MON 1445	2012 for 1 year
	HT	MON 1445	2012 for 1 year

Source: Compiled by ISAAA, 2012.

Political Support to GM Crops in Latin America

The Consejo Agropecuario del Sur (CAS) – Southern Agricultural Council met in Santiago, Chile last October 21-22, 2010, and issued an important statement to endorse agricultural biotechnology development in their countries. CAS is a regional government network of the Ministers of Agriculture of the Southern Cone countries of Latin America, which include Argentina, Brazil, Chile, Uruguay and Paraguay, all important GM crop producers (Crop Biotech Update, 29 October 2010).

The statement said, there is a need to incorporate scientific and technological innovation to meet the challenge of global food production, and achieve competitive and sustainable development of agriculture. Specifically, the members agreed to:

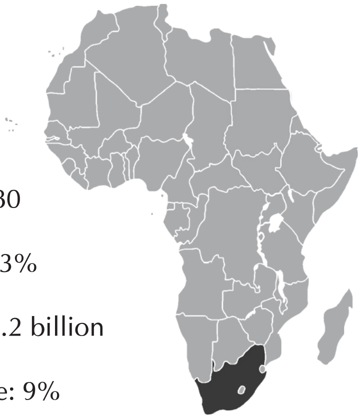
- Deepen and strengthen the regulatory frameworks and instruments to ensure the use of genetically modified organisms.
- Request international organizations to provide technical and financial cooperation in a coordinated manner for the development of GMOs in accordance with the specific demands of the countries of the region.
- Instruct CAS to continue its coordination, harmonization and promotional efforts on activities related to GMOs.

SOUTH AFRICA

Following high commodity grain prices and good maize export opportunities over the past two years, followed by widespread early rains, planting was well underway when this Brief went to press. The hectarage occupied by biotech crops in 2012 continued to increase for the 15th consecutive year, driven mainly by increased areas under maize and soybeans. The estimated total biotech crop area in 2012 will be 2.9 million hectares, compared with 2.3 million hectares in 2011/2012. The total maize area increased by 5%, mainly due to a successful export drive that depleted carry-over of grain stocks, while soybean planting increased by 20%. Approximately 14 million hectares of biotech maize (white and yellow) were planted in the period 2000 to 2012. The total area planted to soybeans increased to 500,000 hectares in 2012 from an estimated 450,000 hectares in 2011, due to higher demand, while the adoption rate of herbicide tolerant soybeans remained at 90% (450,000 hectares). Total cotton area is expected to decline to 11,000 hectares, due to competition from maize and soybeans, and its biotech adoption rate remained at 100%, of which 95%

were stacked traits; herbicide tolerant cotton is used as a mandatory refuge for biotech cotton fields. Various biotech traits are being field tested for maize and cotton, and new biotech crops.

SOUTH AFRICA



Population: 49.5 million

GDP: US$491 billion

GDP per Capita: US$5,680

Agriculture as % GDP: 3.3%

Agricultural GDP: US$16.2 billion

% employed in agriculture: 9%

Arable Land (AL): 14.8 million hectares

Ratio of AL/Population*: 1.3

Major crops:

• Sugarcane	• Maize	• Wheat
• Grapes	• Potato	• Sunflower

Commercialized Biotech Crops:
• HT/Bt/HT-Bt Cotton • HT/Bt/HT-Bt Maize • HT Soybean

Total area under biotech crops and (%) increase in 2012:
2.9 Million Hectares (+26%)

Farm income gain from biotech, 1998-2011: US$922 million

*Ratio: % global arable land / % global population

The mandatory labeling of GM/GMO "goods", ingredients or components, as prescribed in Regulation 7 of the Consumer Protection Act of 2008 that should have entered into force in 2011, has elicited ongoing criticism from stakeholders in the food chain due to its ambiguity and complexity. The Department of Trade and Industry, after having received objections from concerned stakeholders since 2008, finally in 2012, established a task team from departments of Trade & Industry, Health, Agriculture and Science & Technology, to address the conflicts and confusion of the labeling regulation. A revised draft text was released for comments in September. Labelling of GMOs including the process has been removed but other contentious provisions remain. The GMO Executive Council is continuing its study on assessing stacked traits, adventitious presence and low level presence of novel genes. The National Strategy on Biotechnology of 2001 is being updated and redrafted by the Department of Science & Technology and became a Strategy for a Bio-Economy.

It is estimated that a total of 2.83 million commercial hectares of maize will be planted in 2012, up from 2.6 in 2011, in the ratio of 58% white or 1.64 million hectares and 42% yellow grain or 1.19 million hectares. Of the total maize area, 86% or 2.428 million hectares will be biotech. Of the 2.428 million hectares of biotech maize, 34.5% or 837,623 hectares were the single Bt gene, 16.2% or 393,322 hectares herbicide tolerant, and 49.3% or 1.197 million hectares stacked Bt and herbicide tolerant genes. Approximately 16 million hectares of biotech maize (white and yellow) were planted in the 12 year period 2000 to 2012, producing a grain crop of over 40 million metric tons (MT) up to 2012 harvest without a single report of negative effects on humans, animals or the environment (Table 22).

The white maize crop of 1.641 million hectares comprised 80.5% biotech or 1.321 million hectares with the single Bt gene accounting for 498,015 hectares (37.7%), herbicide tolerance at 157,971 hectares (11.9%) and Bt-herbicide tolerance stacks at 665,945 hectares (50.4%).

The supplies of stack gene seed have now become more readily available. The yellow maize planting of 1.189 million hectares comprised 93% or 1.106 million hectares biotech. The biotech breakdown by trait for yellow maize is 31% or 339,608 hectares for the single Bt trait, 21% or 235,351 hectares for herbicide tolerance, and 48% or 530,567 hectares for the stacked Bt and herbicide tolerant product. The seed sales to peasant farmers have become minimal but emergent smallholder and new commercial farmer sales data are incorporated into the statistics as seed sellers regard them as standard customers.

Table 22. Adoption of Biotech Crops in South Africa, 2001 to 2012 (Thousand Hectares)

Year	Total Area of			
	Biotech crops*	Biotech maize	Biotech White Maize	% of Total White Maize
2001	197	166	6	<1
2002	273	236	60	3
2003	404	341	144	8
2004	573	410	147	8
2005	610	456	281	29
2006	1,412	1,232	704	44
2007	1,800	1,607	1,040	62
2008	1,813	1,617	891	56
2009	2,116	1,878	1,212	79
2010	2,229	1,898	1,139	75
2011	2,270	1,873	1,126	72
2012	2,872	2,428	1,322	**80**
Total	**16,569**	**14,142**	**8,072**	

Source: Compiled by ISAAA, 2012.
*Composed of maize, soybean and cotton

Three trends emerged from these data: first, that adoption of biotech is very similar for white and yellow maize; second, that adoption of traits (insect resistance, herbicide tolerance and stacked for both) is similar for white and yellow; and, third, that adoption is reaching saturation as not all plantings require Bt insect resistance due to cost savings when fungicide and insecticide can be applied simultaneously through overhead irrigation when needed, plus some scheduled plantings not being subject to severe stalk borer pressure. Over 92% of maize samples tested are positive for GM traits, pure GM or co-mingled. Some traders import non-GM grain for certain customers.

Total soybean plantings are estimated to have grown by 28% in 2012, compared with 2011 (390,000), to reach a record 500,000 hectares. HT soybean is estimated at 450,000 hectares or 90% of the total area planted. Of the 66 soybean varieties listed for 2011, 18 or 27% were biotech.

Cotton production has continued to decline in recent years due to a movement away from risky dryland to irrigation where it has to compete with maize or soybeans. Area to be planted in 2012 is expected to decline to 11,000 hectares. All of the cotton is expected to be biotech with 95% stacked (Bt/HT) and 5% RR used in refugia. The stacked BtRR®(BollgardII®RR) will be entirely replaced with BtRR® (BollgardII®RR) Flex by 2012. Virtually no conventional cotton is being grown.

The GMO regulatory framework is based on a permit system. There were 294 GMO permits granted from January to 31 October 2012 of which maize accounted for 86%, soybeans for 6.5%, cotton for 2.8%, GM vaccines for 4.4%, and one each for sugarcane and cassava. Maize seed import permits for 2012 (to 31 October) for commercial planting covered 956 MT and exports for 854 MT. South Africa has shifted its commodity GM maize grain exports from Africa to new markets and carry-over stocks almost became depleted. Export permits granted in 2012 amounted to another 750,000 MT from January to October. Permits were also granted for export of 1,200 MT of GM soybeans.

A number of biotech crops have been given approvals for field testing as indicated in Table 23.

The several incidences of African maize stalk borer tolerance/resistance to Bt bio-toxin are being monitored and studied by research teams. The first stacked two Bt traits had been approved for commercial use in 2010 and are being planted, while various other stacked insect resistance genes are being field tested. There are also some varieties which are stacked with herbicide tolerance and others with stacked insect resistance plus stacked herbicide tolerance. At the same time, mandatory use of refugia is being strictly enforced and monitored. To date, cotton bollworm resistance to Bt has been minor but is being monitored as a precaution.

Table 23. Biotech Crop Field Trials as of October 2012

Crop	Trait	Event Name
Maize	Drought tolerance	MON89034 (repeat trials) MON87460
	Insect Resistance/Drought Tolerant	TC1507 x MON810; TC1507 x NK603
		TC1507 x MON810 x NK603
		PHP37048
		PHP36676
		PHP36682
		Bt11 x MIR162 x TC1507 x GA21
	Male Sterility, Fertility Restoration, Visual Marker	DP32138
Cotton	Insect Resistance/Drought Tolerant	Glytol x Twinlink Glytol x TwinLink x COT102
Sugarcane	Altered Sugars	pAUGdf510 (ratoon) pAUGdf510 / pHAN-UGD (new)
Cassava	Altered Sugars	

Note: This information is based on permits granted for experimental field trials, designated as 'trial release'. The term CFT is not used here as many trials are in isolated areas or at research facilities, private or public. Use of the permit may not be applicable in a specific year or not at all, and a GM event may be dropped after testing and may not be applied for commercial release. Event designations only are indicated, company name not shown.
Source: Compiled by Clive James, 2012.

Economic Benefits

It estimated that the economic gains from biotech crops for South Africa for the period 1998 to 2011 was US$922 million and US$98 million for 2011 alone (Brookes and Barfoot, 2013, Forthcoming).

Farmer Testimonies

The brothers **Hannes and Charles Herzog** of Groblersdal in Mpumalanga province planted 70 hectares of cotton in 2010 under central pivot irrigation of which 29 hectares were under stacked gene traits. ***"The 6.7 tons /hectare was the biggest record crop never before achieved on this farm."***

Johannes Sibeko is an emergent new farmer who grew stacked trait maize in the Reitz district of the Free State province. ***"With much rain I could not get into the field but with the stalkborer and herbicide traits I did not have to worry."***

"I have been farming GM maize for five years for a simple reason: insect resistance, increased yield and improved grain quality, and reduced weed pressure," says farmer **Hannes van Wyk.**

Farmer **Piet Janse van Rensburg** is well acquainted with GM crop technology. **"Yield increase and ease of application are inseparable parts of my farming and I am willing to test new technologies,"** Piet says.

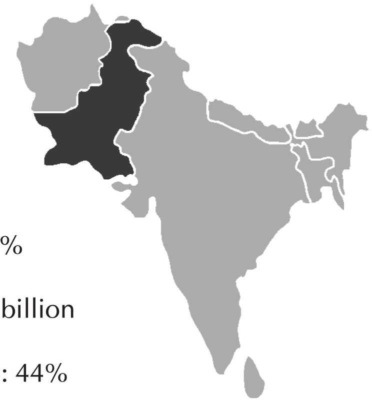
PAKISTAN

2012 was the third year of commercialization of Bt cotton in Pakistan when ~700,000 small farmers planted 2.8 million hectares at an adoption rate of 82% on the total 3.4 million hectares of cotton. This is an increase over 2011, when 2.6 million hectares of Bt cotton, equivalent to 81% of the 3.2 million hectares total cotton were planted by 650,000 farmers. Bt cotton was first approved by the Punjab Seed Council of Pakistan in 2010. In 2011-12, cotton production in Pakistan reached a record 14.8 million bales registering a double digit increase of 25% from the 11.8 million bales in 2010-11. The record 14.8 million bales exceeded the previous high of 14.3 million bales reported in 2004-05. In 2012-13, it is expected that cotton production will surpass the historic benchmark of 15 million bales to an estimated 15.5 million bales, with Bt cotton making an important contribution. In 2010, Pakistan approved the first commercial release of 8 insect resistant Bt cotton varieties and 1 hybrid. By 2012, small cotton farmers in Pakistan could choose from 16 insect resistant Bt cotton varieties approved for commercial cultivation in the three intensive cotton growing provinces of Punjab, Sindh and Balochistan in Pakistan. A surplus of production in 2011-12 allowed Pakistan to increase cotton exports by 77% from 0.937 million bales in 2010-11 (valued at US$500 million) to 1.66 million bales in 2011-12. Bt cotton has helped Pakistan to export significant amount of cotton after meeting growing demand from the domestic textile industry.

With an estimated cotton production of 15.5 million bales in 2012-13, the Pakistan Central Cotton Committee (PCCC), responsible for implementing the national

"Cotton Vision 2015", aims to produce 19.1 million bales of cotton by 2015, which is equivalent to a ~75% increase in production compared to the five year period 2010 to 2015. Pakistan is placing considerable reliance on improved germplasm and biotechnology to increase production by 40-60% in a national strategy to achieve the 19.1 million bales target by 2015. Future developments in biotech cotton look encouraging. Field experiments in Pakistan indicate that biotech cotton, with both Bt and herbicide tolerance traits in varietal and hybrid background, has the potential to further increase yield, reduce insecticides, and deliver substantial net economic benefits of up to US$280 per hectare, equivalent to a national gain of US$800 million annually. These second generation biotech cotton products were field tested in 2011 and are being continued in 2012. They offer Pakistan new opportunities for boosting cotton yields which have been almost stagnant for the last two decades, and there are similar opportunities with insect resistant/herbicide tolerant biotech maize. As part of its on-going research, Pakistan is prioritizing the important disease of cotton caused by leaf curl virus (CLCuV), which can cause significant losses in the country.

PAKISTAN



Population: 167 million

GDP: US$165 billion

GDP per Capita: US$990

Agriculture as % GDP: 20%

Agricultural GDP: US$33 billion

% employed in agriculture: 44%

Arable Land (AL): 22.5 million hectares

Ratio of AL/Population*: 0.5

Major crops:

- Cotton
- Sugarcane
- Maize
- Wheat
- Rice

Commercialized Biotech Crop: Bt Cotton

Total area under biotech crops and (%) increase in 2012:
2.8 Million Hectares (+8)

*Ratio: % global arable land / % global population

Cotton is the most important cash crop of a legion of farmers who grow cotton, mainly in Punjab, Sindh and Balochistan provinces which are divided into zones on the basis of rainfall and temperature (Soomro, 1996). Farmers plant cotton on 2.8 to 3.4 million hectares with an average farm holding of approximately 4 hectares (Rao, 2010. Personal Communication). Thus there are up to 850,000 cotton farmers in the country (based on 3.4 million hectares and an average holding size of 4 hectares). Punjab is the largest cotton growing region occupying almost 80% of total cotton in

Pakistan with the balance of cotton hectarage in the Sindh with less in Balochistan and North West Frontier Province (NWFP). Both Punjab and Sindh farmers mainly grow open pollinated varieties (OPVs) of cotton with almost 100% assured irrigation facility throughout the cotton season. Kharif (monsoon season) is the major season for cotton cultivation which begins in April-June and harvested in October-December. ISAAA Brief 43 (James, 2011) provides a detailed overview of agriculture and cotton crop and also highlights the composition of value of major crops and distribution of cotton crop in four major cotton growing Provinces in Pakistan.

Commercial Approval of Bt Cotton in Pakistan

In concurrence with the federal government national biosafety framework, the Punjab Seed Council (PSC) under the Ministry of Agriculture of the Punjab province, for the first time decided to officially approve the commercial cultivation of 8 insect resistant Bt cotton varieties and one Bt cotton hybrid at their 39th meeting held on 31 March 2010. This decision of the Punjab Seed Council was considered very important particularly because a decision had not been declared at that time by the National Biosafety Committee (NBC) of the Federal Ministry of Environment. The Federal Ministry of Food and Agriculture (MinFA) endorsed the PSC's decision for commercial release of Bt cotton in the meeting held on 15 April 2010. Accordingly, the Punjab Seed Council (PSC) approved the release of two events of Bt cotton namely MON531 (*cry1Ac* gene) and the GFM event expressing the fusion gene *cry1Ac* and *cry1Ab*. A total of 8 cotton varieties expressing MON531 and one hybrid expressing the fusion gene *cry1Ac* and *cry1Ab* received approval for commercial cultivation in 2010 (Punjab Seed Council, 2010; NBC, 2010). In 2011, the Punjab Seed Council approved the renewal of four Bt cotton varieties including IR-1524, FH-113, Ali Akbar-802 and Neelam-121, which was conditionally approved in 2010 for one year, for approval reconsideration subsequent to improving fiber characteristics (Pakistan Today, 2011).

In Feb 2012, the Punjab Seed Council (PSC) officially approved 8 new insect resistant Bt cotton varieties including four new unconditional approval for insect resistant Bt cotton varieties namely FH-114, CIM-598, SITARA-009 and A-ONE; and one year conditional approval for four additional Bt cotton varieties namely TARZAN-1, NS-141, IR-NIBGE-3 and MNH-886. Similarly, the PSC also renewed three insect resistant Bt cotton varieties including IR-1524, ALI AKBAR-802 and NEELAM-121 which received one year conditional approval in 2011. One Bt cotton variety FH-113 was discontinued in 2012. Therefore, in 2012, small cotton farmers in Pakistan could choose from 16 insect resistant Bt cotton varieties for commercial cultivation in three intensive cotton growing provinces of Punjab, Sindh and Balochistan in Pakistan. Accordingly, all 16 approved Bt cotton varieties (including one Bt cotton hybrid) contains one of the two released events of Bt cotton namely MON531 (*cry1Ac* gene) and the GFM event expressing the fusion gene *cry1Ac* and *cry1Ab*.

It is important to note that all approved Bt cotton varieties and a hybrid have undergone more than 5 to 6 years of field trials in accordance to the procedures implemented by the Pakistan Central Cotton Committee (PCCC). Of the 16 approved Bt cotton varieties (including a hybrid) 15 Bt cotton varieties expressing cry1Ac gene (MON531 event) namely IR-3701, Ali Akbar-703, MG-6, Sitara-008, IR-1524, Ali Akbar-802, Neelum-121, FH-114, CIM-598, SITARA-009, A-ONE, TARZAN-1, NS-141, IR-NIBGE-3 and MNH-886 have been developed by public and private sector institutes, whereas the one Bt cotton hybrid GM-2085, expressing fusion gene *cry1Ac* and *cry1A*, has been developed by a local private seed company. Out of the 16 approved Bt cotton varieties, 12 received unconditional approval, and four varieties received one year approval with the condition that developers must submit field performance and monitoring report to the Punjab Seed Council. In addition, Bt cotton hybrid GM-2085 received approval for two years in 2010 with the condition that hybrid would be reconsidered by the PSC after fulfilling the requirement of the Federal Seed Certification and Registration Department (FSC&RD) in the Distinctness, Uniformity and Stability (DUS) trials.

As per Table 24, public sector institutes received approval for 8 insect resistant Bt cotton varieties whereas 8 Bt cotton varieties (including one hybrid) were approved for local private seed companies in Pakistan. These public and private sector institutions included Nuclear Institute for Biotechnology and Genetic Engineering (NIBGE), Faisalabad; Cotton Research Institute of Ayub Agricultural Research Institute (AARI), Faisalabad; Central Cotton Research Institute (CCRI), Multan; Ali Akbar Seeds, Multan; Nawab Gurmani Foundation; Guard Agricultural Research Services, Lahore; Neelum Seeds, Multan; Sitara Seeds and Four Brothers Seeds Corporation.

In 2010, Pakistan became the thirteenth country globally to officially plant Bt cotton. Thus, the Bt cotton farmers of Pakistan, for the first time, joined the exclusive club of biotech cotton growing farmers from the USA, China, India, Australia, South Africa, Brazil, Argentina, Columbia, Mexico, Costa Rica, Myanmar and Burkina Faso which control a very large proportion of global cotton production and trade. In the third year of commercialization, 2012, Bt cotton was planted by ~700,000 farmers on 2.8 million hectares, occupying a substantial 82% of the total 3.4 million hectares of cotton area planted in Pakistan; this compares with 2.6 million hectares of Bt cotton in 2011, equivalent to 81% of the 3.2 million hectares cotton area planted nationally (Table 25). Therefore, in 2012, Pakistan planted 2.8 million hectares of biotech cotton which is over 10% of total biotech cotton area of the world.

After the official approval and planting of Bt cotton crop for three consecutive years, the country harvested an all time high level of cotton production at 14.81 million bales registering a double digit increase of 26.63% from 11.69 million bales in 2010-11, the first year of the official approval of Bt cotton plantings by the Punjab Seed Council (PSC) of Pakistan. The record increase in cotton production is the highest ever recorded cotton production of 14.81 million bales in 2011-12 higher than the previous high record of 14.31 million bales in 2004-05. It is expected that in the third year

Table 24. Commercial Release of Different Bt Cotton Varieties and Hybrid in Pakistan Between 2010 and 2012

Crop	Event	Variety (*hybrid)	Developer	Status	Date of Approval
Cotton	*cry1Ac* gene (MON531 event)	IR-3701	Nuclear Institute for Biotechnology and Genetic Engineering (NIBGE), Faisalabad	Approved in 2010	Punjab Seed Council (PSC) approved it on 31 March 2010 Federal Ministry for Food and Agriculture approval on 15 April 2010
Cotton	*cry1Ac* gene (MON531 event)	Ali Akbar-703	M/s Ali Akbar Seeds, Multan	Approved in 2010	As Above
Cotton	*cry1Ac* gene (MON531 event)	MG-6	M/s Nawab Gurmani Foundation	Approved in 2010	As Above
Cotton	*cry1Ac* gene (MON531 event)	Sitara-008	M/s Nawab Gurmani Foundation	Approved in 2010	As Above
Cotton	fusion gene (*cry1Ac* and *cry1Ab*)/GFM event	GM-2085 (*hybrid)	M/s Guard Agricultural Research Services, Lahore	Approved in 2010 (two year approval, DUS trial data to be submitted to FSC&RD)	As Above
Cotton	*cry1Ac* gene (MON531 event)	IR-1524	NIBGE, Faisalabad	Renewed in 2012	Punjab Seed Council (PSC) approved it on 31 March 2010 and renewed on 16 Feb 2012
Cotton	*cry1Ac* gene (MON531 event)	Ali Akbar-802	M/s. Ali Akbar Seeds, Multan	Renewed in 2012	Punjab Seed Council (PSC) approved it on 31 March 2010 and renewed on 16 Feb 2012
Cotton	*cry1Ac* gene (MON531 event)	Neelum-121	M/s. Neelum Seeds, Multan	Renewed in 2012	Punjab Seed Council (PSC) approved it on 31 March 2010 and renewed on 16 Feb 2012
Cotton	*cry1Ac* gene (MON531 event	FH-114	Cotton Research Institute, AARI, Faisalabad	Approved in 2012	Punjab Seed Council (PSC) approved it on 16 Feb 2012
Cotton	*cry1Ac* gene (MON531 event)	CIM-598	Central Cotton Research Institution (CCRI), Multan	Approved in 2012	As Above
Cotton	*cry1Ac* gene (MON531 event)	SITARA-009	Sitara Seed Company	Approved in 2012	As Above

Table 24. Commercial Release of Different Bt Cotton Varieties and Hybrid in Pakistan Between 2010 and 2012

Crop	Event	Variety (*hybrid)	Developer	Status	Date of Approval
Cotton	*cry1Ac* gene (MON531 event)	A-ONE	M/s Weal-AG Seed	Approved in 2012	As Above
Cotton	*cry1Ac* gene (MON531 event)	TARZAN-1	Four Brothers Seeds Corporation Pakistan Pvt. Ltd.	One year Approval in 2012 (Conditional approval for field performance/monitoring)	As Above
Cotton	*cry1Ac* gene (MON531 event)	NS-141	M/s Neelum Seeds, Multan	One year Approval in 2012 (Conditional approval for field performance/monitoring)	As Above
Cotton	*cry1Ac* gene (MON531 event)	IR-NIBGE-3	NIBGE, Faisalabad	One year Approval in 2012 (Conditional approval for field performance/monitoring)	As Above
Cotton	*cry1Ac* gene (MON531 event)	MNH-886	Central Cotton Research Institution (CCRI), Multan	One year Approval in 2012 (Conditional approval for field performance/monitoring)	As Above

Source: Punjab Seed Council (PSC), 2010 & 2012, Pakistan Today, 2011 & 2012; Ministry of Textile Industry, 2012.

Table 25. Adoption of Bt Cotton in Pakistan, 2012

Year	Adoption of Bt Cotton (Mha)	Total Cotton (Mha)	% Adoption
2010 - 11	2.4	3.1	75%
2011 - 12	2.6	3.2	81%
2012 - 13	2.8	3.4	82%

Source: Compiled by ISAAA, 2012.

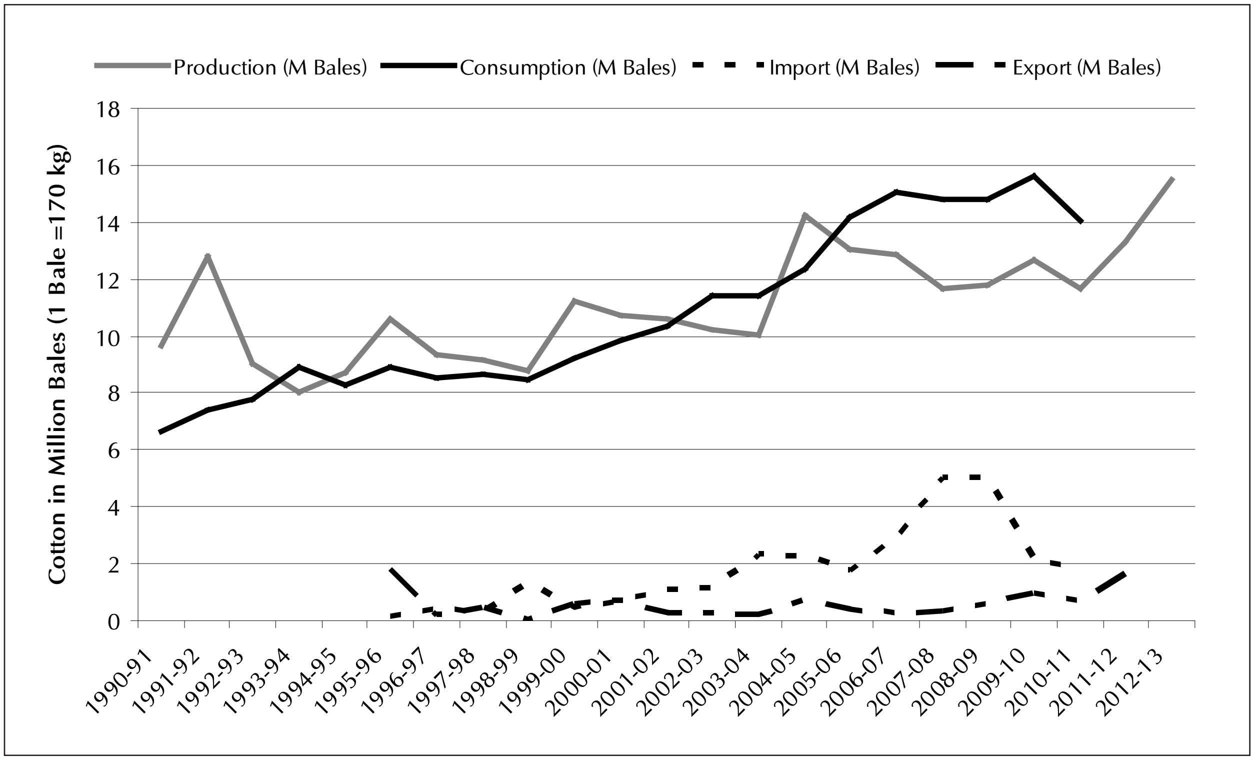
of commercialization of Bt cotton in 2012-13, the cotton production would surpass the historic benchmark of 15 million bales to an estimated 15.5 million bales accentuated by the high adoption of Bt cotton by small farmers in the country (PCGA, 2012; Business Recorder, 2012a; PCCC, 2011; Daily Times, 2012). With surplus production of raw cotton in 2011-12, the raw cotton export from Pakistan registered a substantial growth of 78% to 1.66 million bales in 2011-12 from 0.937 million bales in 2010-11, worth half a billion (~US$462 million) in 2011-12. This is the first time the country has reported a significant export of raw cotton after meeting growing demand from domestic textile industry in the country (Ministry of Textile Industry, 2012; PCGA, 2012; Business Recorder, 2012b).

Based on preliminary field trials, and assuming deployment of biotech cotton at 90% with both insect and herbicide tolerance, there is a potential to substantially increase farmer income by up to US$280 per hectare (Pakistan Textile Journal, 2010; Kakakhel, 2010). In order to optimize the benefits from the new technologies, the province of Punjab organized a vigorous campaign from 2010 to 2012 to implement insect resistant management and effectively control whitefly, the vector of the lethal cotton leaf curl virus (CLCuV). Guidelines for marketing of Bt cotton seeds were issued by the Directorate General of Agriculture Extension of Punjab to ensure genetic purity, germination, refuge and product labeling of Bt cotton packets for optimizing the full potential of Bt cotton seeds in farmers field (Directorate General of Agriculture, 2010).

It is important to note that the area under cotton has not increased substantially over the last two decades from 2.7 million hectares in 1990-91 to 3.4 million hectares in 2012-13. During the same period, cotton yields remained almost stagnant at 550 kg to 750 kg of lint per hectare which is a major cause of concern for the growing textile industry (Figure 26). As a result, annual cotton production has stalled at between 10 to 12 million bales whilst demand for cotton doubled from 6.6 million bales in 1990-91 to 14.05 million bales in 2011-12. In the past, the country has witnessed a dismal growth in cotton production, which remained at less than 10 million bales from 1995 to 99 and around 12 million bales from 2000 to 2011 before touching the high level of 14.81 million bales in 2011-12, the highest ever raw cotton production in the country. These low yields are attributed to various factors including floods, outbreak of severe cotton leaf curl virus (CLCuV) and the emergence of different strains of bollworms like American, spotted and pink which caused the worst damage in the Sindh and Punjab provinces (Hussain & Awan, 2011; PCGA, 2012).

In 2004-05 the country produced a record cotton crop of 14.5 million bales as a result of favorable climatic conditions. Pakistan was a net cotton exporter in the early 1990s but is now a major importer to meet the growing demand of the domestic cotton based industry. Over the last five years, Pakistan has been importing 3 to 5 million bales of cotton per year which costs the national exchequer between US$3 to US$5 million per year, widening further the trade deficit to record levels. In 2010-11, a record cotton production of 14 million bales was expected, however, 2 to 2.5 million bales of cotton were lost due to severe floods, which destroyed 0.7 million hectares of cotton

Figure 26. Cotton Production, Consumption, Export and Import in Pakistan, 1990 to 2012

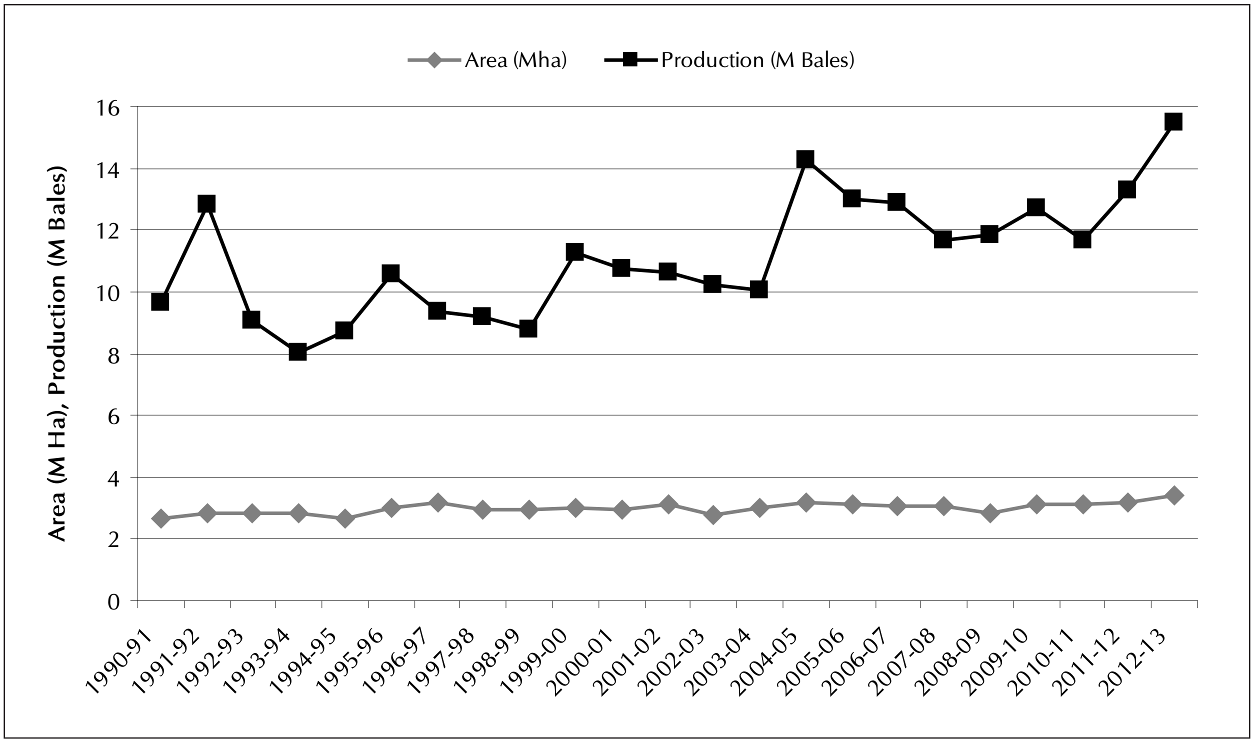


Source: PCCC, 2012; PCGA, 2012.

in the major cotton growing provinces of Punjab and Sindh, resulting in a significantly lowered production of only 12 million bales. However, the country produced a record cotton production of 14.8 million bales in 2011-12 due to the high adoption of Bt cotton, low incidence of CLCuV and favorable climatic conditions. In 2011-12, the cotton area was increased slightly from 3.1 million hectares in 2010-11 to 3.2 million hectares in 2011-12. It is expected that the country would harvest bountiful cotton and breach the historic benchmark of 15 million bales to 15.5 million bales in 2012-13 cotton season (Figure 27).

In contrast to the situation in Pakistan, over the last 11 years the top three cotton producers in the world, China, India and USA have substantially increased cotton yield over the same period, out competing others, including Pakistan, in the world cotton market. For instance, India has doubled its cotton production from 13 million bales in 2001 to 35.3 million bales in 2011-12. It is noteworthy, that all three lead cotton countries have successfully deployed biotech cotton varieties and hybrids which confer resistance to major insect pests and tolerance to herbicides thus benefiting from cost effective and efficient management of insect pest and weed control. Consequently, farmers in these countries have generated substantial additional income by reducing losses caused by insect pests and

Figure 27. Area and Production of Cotton in Pakistan, 2012



Source: PCCC, 2012; PCGA, 2012.

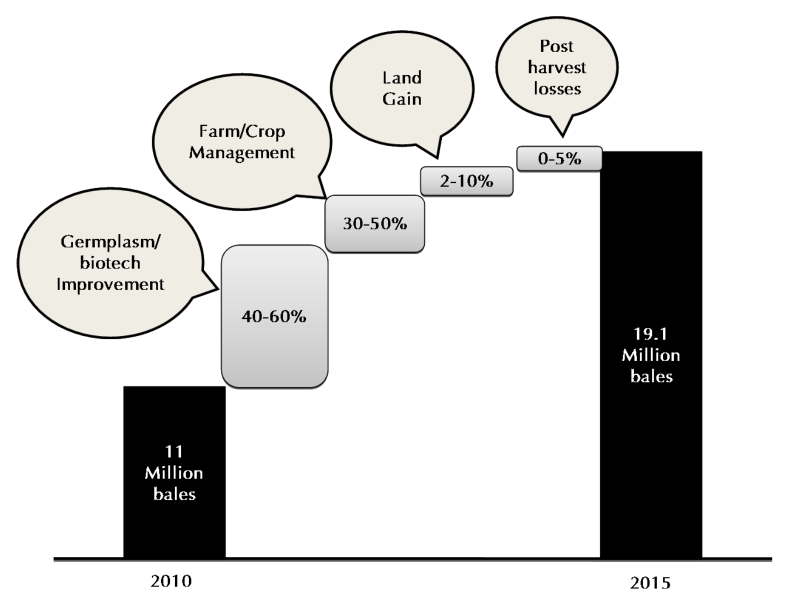
weeds, significantly reduced insecticide applications and reaped bumper harvests of competitively priced cotton for the international market.

The All Pakistan Textile Mills Association (APTMA) and the Pakistan Cotton Ginners Association (PCGA) estimated that the textile industry's raw cotton requirements would be 20.1 million bales by 2015 comprising 66% of medium staple, 26% long staple and 8% extra long staple cotton. To meet these demands, Pakistan's "Cotton Vision 2015" concluded that this would require an increase of 5% in cotton hectarage in Balochistan and in the North West Frontier Province (NWFP), an annual average of 5% increase in yield, introduction of CLCuV resistant Bt cotton varieties and hybrids, and a strengthening of R&D and infrastructure of cotton institutes in Pakistan. Accordingly, the Pakistan Central Cotton Committee (PCCC), that is responsible for implementing the national "Cotton Vision 2015", aims to produce 19.1 million bales of cotton by 2015, up from the 11 million bales of cotton in 2010, and equivalent to a 74% increase in the five year period 2010 to 2015. In 2012, the cotton production already crossed the half way mark to 14.8 million bales and is expected to produce 19.1 million bales by 2015. The Department of Agriculture of Pakistan's Punjab Province issued a recent report "Investment prospects in agriculture sector" that lays considerable emphasis on the production of quality Bt cotton hybrid seeds to achieve the target of 19.1 million bales by 2015 (Punjab Agriculture Department; 2012a). Similarly, the Government of Pakistan and the PCCC places considerable emphasis on improved germplasm and biotechnology to increase cotton production by 40-60% which is a key component of the national strategy to achieve a target of 19.1 million bales by 2015. The other important elements that are expected to contribute to enhanced cotton production include farm and crop management practices, an increase in cotton area, and a reduction of post-harvest losses (Figure 28). In 2005-06, Pakistan's federal government launched an ambitious plan to enhance cotton production to 20.7 million bales by 2015 – a 60% increase over 2005-06 production.

Socio Economic Benefits of Bt Cotton in Pakistan

Various observers have noted that Pakistan like many other developing countries was probably growing Bt cotton varieties unofficially as early as 2002. The Bt cotton varieties of poor seed and fiber quality did not contribute significantly to cotton production because most of them were susceptible to cotton leaf curl virus (CLCuV), requiring high inputs (Ahsan, 2009). The situation changed in 2010 when the Punjab Seed Corporation (PSB) officially approved 8 Bt cotton varieties and one hybrid containing event MON531 and GFM event. In 2012, Pakistan planted 2.8 million hectares of officially approved Bt cotton varieties and a hybrid, equivalent, to an 82% adoption rate on the

Figure 28. Pakistan's Roadmap to Cotton Vision 2015



Source: Adopted from PCCC, 2011.

3.4 million hectares of cotton hectarage; this compares with 2.6 million hectares of Bt cotton at an adoption rate of 81% on the 3.2 million hectares of national cotton crop in 2011.

The official approval of Bt cotton in 2010 was spurred by the demand for genuine good quality Bt cotton in the country with the following specifications: resistant to CLCuV; well adapted for the different ecologies; meet required fiber quality standards; other desirable features required for the release of a normal commercial variety (Ahsan and Altaf 2009). Another milestone achievement in 2010 was the signing of the memorandum of understanding (MOU) between the Ministry of Food and Agriculture (MINFA) of the Government of Pakistan and Monsanto for introducing advanced Bt cotton and hybrid seed technology for the development of the agriculture sector. The MOU allows Pakistan to harness the benefits of the new generation stacked technology in cotton including the double gene Bt cotton (Bollgard®II), herbicide tolerant cotton (BGII-RRFlex) and other technologies developed for maize in the country (The Nation, 2010). In 2012, the Agriculture Department of the Govt of Punjab, Pakistan issued a document "Strategy and Initiative of Punjab Government in Agriculture Sector" that provides the government guarantee to Monsanto for the technology fee for the use of its latest cotton technologies including Bollgard®II & BGII-RRFlex cotton (Punjab Agriculture Department, 2012b).

In addition to the 2010 study, Nazli et al. published a recent study in 2012 that demonstrates the positive economic impact of the available Bt varieties on farmers' well being in Pakistan. The study concludes that per acre yield gains for medium and large farmers are higher than for small farmers, contradicting the study by Ali and Abdulai (2010), who reported a larger gain in yield per acre for small farmers as compared to medium and large farmers. ***"The impact of Bt cotton adoption on yield is lower (125 Kg/acre) for small farmers than for large farmers (246 Kg/acre)"*** (Nazli et al. 2012).

In 2012, Kouser & Qaim presented a research study on "Valuing a financial, health and environmental benefits of Bt cotton in Pakistan", which concluded that Bt cotton adoption results in significantly lower chemical pesticide use, higher yields, and higher gross margins, which is consistent with the results from other countries. The study noted that the lower pesticide use brings about significant health advantages in terms of reduced incidence of acute pesticide poisoning, and environmental advantages in terms of higher farmland biodiversity and lower soil and groundwater contamination. ***"These positive externalities are valued at US$79 per acre (US$195/hectare), which adds another 39% to the benefits in terms of higher gross margins. Adding up financial and external benefits results in total benefits of US$284 per acre (US$701/hectare), or US$1.7 billion for the entire Bt cotton area in Pakistan"*** (Kouser and Qaim, 2012). Note that, the total benefits of US$284 per acre (US$701/hectare) include the monetized health and environmental benefits of US$79 per acre (US$195/hectare). Thus, effectively, farmers reaped only the direct benefits of US$203 per acre (US$501/hectare) in 2010-11 which is high (average is about US$280 per hectare) because it was calculated when the prevailing cotton prices were high.

The preliminary data from the field experiments in Pakistan indicate that biotech cotton, with both Bt and herbicide tolerance traits in varietal and hybrid background, has the potential to increase yield, result in significant savings of insecticides, and deliver substantial net economic benefits of up to US$280 per hectare; this could contribute an additional US$800 million annually to the farm economy of Pakistan. Thus, the second generation biotech crops, conferring both insect resistance and herbicide tolerance in cotton and maize, which have been field tested in 2011/2012, offer Pakistan new opportunities for boosting cotton yields which have been almost stagnant for the last two decades. Compared with other countries, like India that has derived significant yield benefits from Bt cotton, Pakistan has to contend with the possibility that significant yield gains from Bt cotton can be eroded by cotton leaf curl virus (CLCuV).

Efforts to develop CLCuV resistant cotton have been initiated by various research institutions in Pakistan. Recently, a collaborative work with the Institute of Agricultural Sciences and National Centre of Excellence in Molecular Biology, University of Punjab, Lahore and University of Toronto, Canada, under the coordination of the Punjab Agriculture Research Board has developed a CLCuV-resistant cotton plant through transgenic RNA interference (RNAi) technology. Continuing on the progress made in developing transgenic tobacco plants resistant to a virus disease, the scientists used similar technology in cotton. Virus free cotton plants were observed in the trials and this has been verified by grafting the transgenic RNAi plants on severely CLCuV-infected plants. The researchers also said that RNAi technology has efficiently blocked viral multiplication when the virus was either agroinoculated or transmitted by the insect vector whitely. It is hoped that new virus-resistant GM cotton seeds would be available in the market in three years (The News International, 10 November, 2012).

Food, feed and fiber crops are major contributors to Pakistan's GDP, and biotech crops could make a significant contribution at this critical time, when Pakistan is trying to desperately recover from the two worst consecutive floods in its history.

URUGUAY

Uruguay increased its biotech plantings of soybean and maize to ~1.34 million hectares in 2012, an increase of about 3%. Herbicide tolerant soybean now occupies 100% of the national soybean hectarage at a record 1.2 million hectares. Biotech maize occupied ~145,000 hectares in 2012 – this was the 9th year for Uruguay to plant biotech maize. Of the 145,000 hectares of biotech maize, 80% was the stacked Bt/HT product. Remarkably, Uruguay approved five events on the same day in early 2011. In September 2012 the stacked biotech soybean with insect resistance and herbicide tolerance,

Bt/RR2Y, was approved for commercialization. Thus, in the short space of only two years, the efficient, science–based regulation system in Uruguay has approved a total of 9 products, emulating its neighbor Brazil which approved 14 products in two years, 2010 and 2011. Uruguay has enhanced farm income from biotech soybean and maize of US$101 million in the period 2000 to 2011 and for 2011 alone at US$16.5 million.

URUGUAY

Population: 3.3 million

GDP: US$31.5 billion

GDP per Capita: US$ 9,010

Agriculture as % GDP: 10%

Agricultural GDP: US$3.2 billion

% employed in agriculture: 11.1%

Arable Land (AL): 1.35 million hectares

Ratio of AL/Population*: 1.6

Major crops:
- Rice
- Wheat
- Maize
- Barley
- Soybean

Commercialized Biotech Crops:
- HT Soybean
- Bt/HT Maize

Total area under biotech crops and (%) increase in 2012:
1.34 Million Hectares (+8%)

Farm income gain from biotech, 2000 to 2011: US$101 million

*Ratio: % global arable land / % global population

Uruguay, which introduced biotech soybean in 1996, followed by Bt maize in 2003 increased its total biotech crop area once again in 2012 to reach 1.34 million hectares. A significant increase was recorded in the hectarage of herbicide tolerant soybean which occupies 100% of the national soybean hectarage of 1.2 million hectares. Biotech maize was planted on 145,000 hectares in 2012 when it was planted for the ninth year; 80% of the biotech maize was the stacked Bt/HT product biotech maize which was first approved in Uruguay in 2003. Table 26 shows the biotech maize and soybean approvals from 2003 to 2012 while Table 27 lists the approval for field testing in 2012.

Benefits from Biotech Crops in Uruguay

Uruguay is estimated to have enhanced farm income from biotech soybean and maize of US$101 million in the period 2000 to 2011 and the benefits for 2011 alone is estimated at US$16.5 million (Brookes and Barfoot, 2013, Forthcoming).

Table 26. Commercial Approvals for Planting, Food and Feed in Uruguay, 2003 to 2012

Crop	Trait	Event	Year
Maize	Insect Resistance (IR)	Mon 810	2003
	IR	Bt 11	2004
	IR/ Herbicide Tolerance (HT)	TC1507	2011
	HT	GA21	2011
	HT	NK603	2011
	HT/IR	GA21 x BT11	2011
	IR /HT	MON810 x NK603	2011
	IR /HT	TC 1507 x NK 603	2012
	IR /HT	MON 89034 x TC1507 x NK603	2012
	IR /HT	Bt11 x MIR162 x GA21	2012
Soybean	HT	40-3-2	1996
	HT	A-5547 - 127	2012
	HT	A-2704 - 12	2012
	IR/HT	MON 89788 x MON87701	2012

Source: Compiled by ISAAA, 2012.

Table 27. Approval for Field Testing in Uruguay in 2012

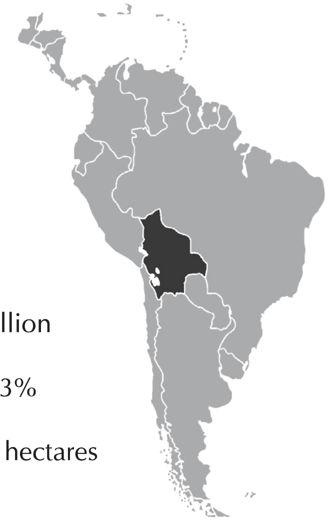
Crop	Trait	Event	Year
Corn	IR/HT	MON89034 x NK603	Research Trial
Soybean	HT	MON 89788 (RR2Y)	Counter Season Production
	HT/HT	MON 87708 x 89788 (RR + Dicamba)	Counter Season Production

Source: Compiled by ISAAA, 2012.

BOLIVIA

> **RR®soybean was grown on an estimated 1.0 million hectares in 2012 in Bolivia – this is 11% higher, than the 910,000 hectares in 2011. The adoption rate of RR®soybean in 2012 was estimated at 91% of the total 1.1 million hectares – this compares with 92% of 990,000 total hectares in 2011. In 2008, Bolivia became the tenth country to officially grow RR®soybean of 600,000 hectares. Thus, the growth rate between 2008 and 2012 has been significant with almost a doubling of RR®soybean hectares.**

BOLIVIA



Population: 10.1 million

GDP: US$17.4 billion

GDP per Capita: US$1,630

Agriculture as % GDP: 14%

Agricultural GDP: US$2.4 billion

% employed in agriculture: 43%

Arable Land (AL): 3.6 million hectares

Ratio of AL/Population*: 2.0

Major crops:

- Soybean
- Maize
- Coffee
- Cocoa
- Sugarcane
- Cotton
- Potato

Commercialized Biotech Crop: HT Soybean

Total area under biotech crops and (%) increase in 2011:
1 Million Hectares (+11%)

Farm income gain from biotech, 2011: US$200 million

*Ratio: % global arable land / % global population

Bolivia is a small country in the Andean region of Latin America with a population of 10 million and a GDP of approximately US$20 billion. Agriculture contributes approximately 14% to GDP and employs just over 43% of the total labor force. Agriculture in the eastern Amazon region of Bolivia benefits from rich soils and modern agriculture which is in contrast to the traditional subsistence farming in the mountainous west of the country. There are approximately 2 million hectares of cropland in Bolivia, and soybean is a major crop in the eastern region. In 2007, Bolivia grew approximately 1 million hectares of soybean (960,000 hectares) with an average yield of 1.97 tons per hectare to generate an annual production of 2 million tons. Bolivia is a major exporter of soybeans (~5% of total exports) in the form of beans, oil, and cake. Current yields are estimated at an average of 2.3 tons per hectare according to the National Association of Oil Seed producers (Anapao) which reports that 51 varieties were available on the market in 2011, six of which were introduced as new varieties in 2011.

Certified Seed in Bolivia

It is not a well recognized fact that the seed industry business in Bolivia is exemplary in the organization and use of certified seeds. In 2008, the percentage of certified soybeans in Bolivia reached a high of 75% despite the fact that in Bolivia there is a tradition, which is constantly changing, for smaller farmers to save their own soybean seed. However, smaller farmers are becoming increasingly aware of the benefits associated with certified seed and are adopting it within their traditional farming systems, resulting in a high level of adoption of 75% in 2008. At the national level and at the Santa Cruz State level, Bolivia has well organized extension programs that provide technical assistance to seed producers regarding the value of high quality certified seed with a focus on the significant benefits it offers smaller low-income farmers. The presence of an effective and efficient certified seed industry in Bolivia greatly facilitates access and adoption of certified RR®soybean seed which is used not only by the larger farmers but increasingly by smaller subsistence farmers.

IFPRI reports that 97% of the soybeans are grown in Santa Cruz where most of the producers are relatively small farmers (classified as less than 50 hectares), although the majority of the production is by larger farms.

It is estimated that RR®soybean was grown on 91% or 1.0 million hectares of the estimated total hectarage of approximately 1.1 million hectares of soybean planted in Bolivia in 2012.

According to the most recent estimates of global hectarage of soybean (FAO, 2010 data), Bolivia ranks eighth in the world with 1.1 million hectares, after the USA (31 million hectares), Brazil (23.3), Argentina (18.1), India (9.2), China (8.5), Paraguay (2.7), and Canada (1.5). Of the top eight soybean countries, six (USA, Argentina, Brazil, Paraguay, Bolivia and Canada) grow RR®soybean. Exports of soybean from Bolivia in 2011 were worth US$309 million – they were the most important agricultural export and the third largest of all Bolivian exports

In 2008, Bolivia became the tenth soybean country to officially grow RR®soybean with 600,000 hectares planted, equivalent to 63% of the total national hectarage of 960,000 hectares. RR®soybean has been adopted on extensive hectarages in Bolivia's two neighboring countries of Brazil (currently at 36.6 million hectares) and Paraguay (currently at 3.4 million hectares) for many years. It is not clear at this stage what the potential impact of the Bill "Law of the Productive Revolution" introduced on 26 June 2011 will have on future production of RR®soybean. The law prohibits the introduction of modified organisms into Bolivia, if the country is the centre of origin and diversity. This leaves open the option of introducing transgenic crops for which Bolivia is not the center of origin. Farmers are encouraging Government to introduce biotech varieties of crops such as cotton, rice, sugarcane, which are of interest to Bolivian farmers.

Benefits from RR®soybean in Bolivia

Paz et al. (2008) noted that Bolivia is one of the few countries in Latin America where there are a significant number of small farmers producing soybeans. Soybeans are important, contributing 4.6% of GDP and 10% of total exports. Paz et al. (2008) noted that despite the lack of government incentive, RR®soybeans continue to expand because cost-benefit analysis favors RR®soybean over conventional. More specifically, the partial budget analysis (Table 28) indicates that the net benefits favor RR®soybean over conventional, which is approximately US$200 (US$196) per hectare. The principal benefits, include a 30% increase in yield, a 22% savings on herbicides and more modest savings in labor and other variable costs; in some cases, cost of RR® seed was lower than conventional seed. Based on a net return of US$196 per hectare with 910,000 hectares of RR®soybeans, the 2012 benefits at the national level could be of the order of approximately US$200 million, which is a significant benefit for a small poor country such as Bolivia.

Table 28. Partial Budget for Production of RR®soybean and its Conventional Equivalent in Bolivia

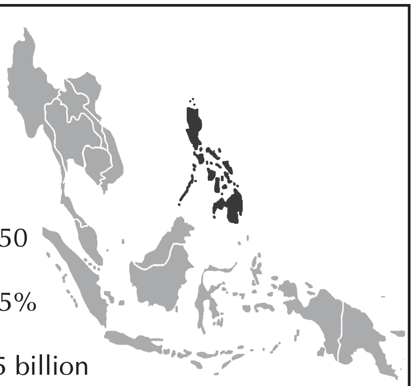
Variable	Non-RR	RR
Yield (t/ha)*	1.47	1.91
Price (US$/t)*	409.32	398.59
Gross Benefit (US$/ha)*	600.26	780.83
Costs (US$/ha)		
Seed	23.46	26.78
Herbicides	41.53	32.25
Insecticides	21.34	24.12
Fungicides	37.93	37.86
Labor cost for chemical input application	4.98	5.03
Machinery	55.02	52.13
All other labor costs*	3.50	2.25
Other variable costs	161.74	146.67
Net Benefits (US$/ha)*	436.53	632.54
Difference RR – non RR (US$/ha)		196.01

Source: IPFRI Annual Report, Paz et al, 2008.

PHILIPPINES

In 2012, the area planted to biotech maize in the Philippines is projected to increase to 750,000 hectares, up 16% from the estimated hectares of biotech maize in 2011. Notably, the area occupied in 2011 by the stacked traits of Bt/HT maize is 675,000 hectares, compared with only 545,000 hectares in 2011, with the stacked trait maize occupying 90% of total biotech maize hectares in 2012, reflecting the preference of farmers for stacked traits and the superior benefits they offer over a single trait. Farm level economic gains from biotech maize in the Philippines in the period 2003 to 2011 is estimated at US$264.5 million and for 2010 alone at US$93.6 million.

PHILIPPINES



Population: 89.7 million

GDP: US$167 billion

GDP per Capita: US$1,850

Agriculture as % GDP: 15%

Agricultural GDP: US$25 billion

% employed in agriculture: 37%

Arable Land (AL): 5.1 million hectares

Ratio of AL/Population*: 0.3

Major crops:
- Sugarcane
- Coconut
- Rice
- Maize
- Banana
- Cassava
- Pineapple
- Mango

Commercialized Biotech Crop: Bt/HT/Bt-HT Maize

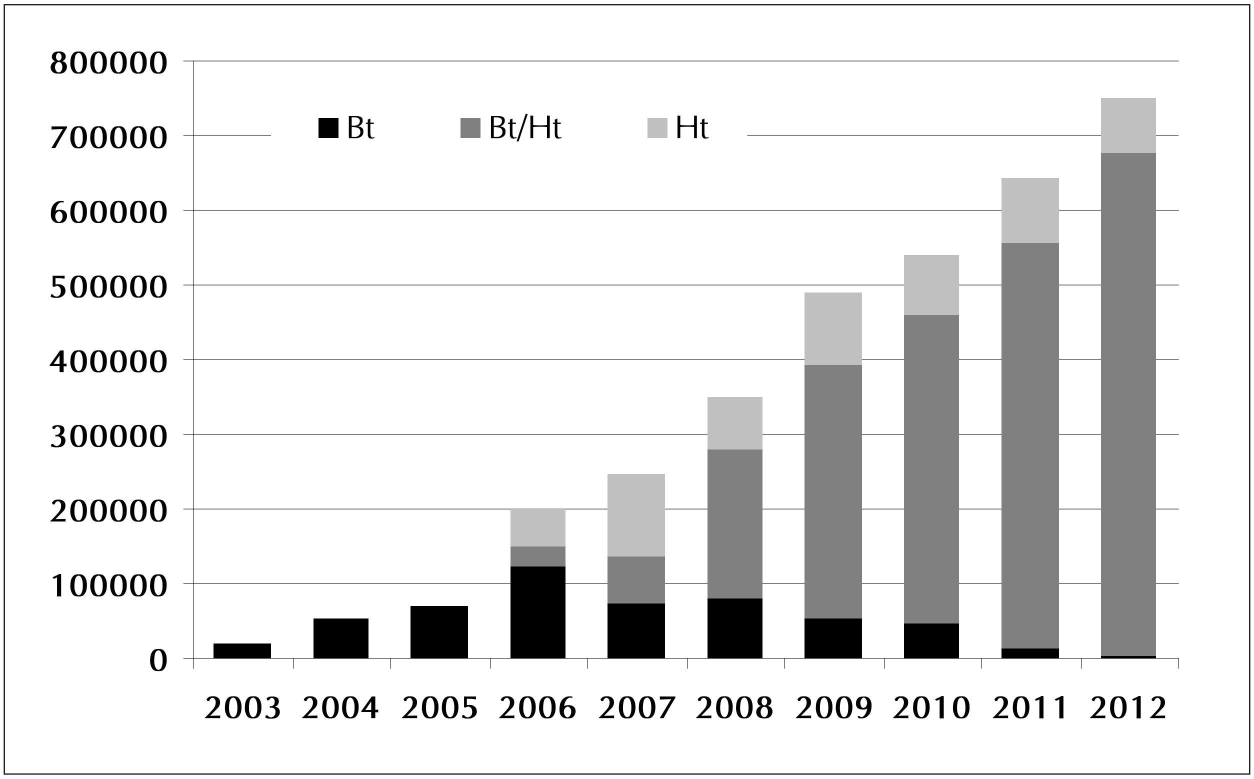
Total area under biotech crops and (%) increase in 2012:
750,000 Hectares (+16)

Increased farm income for 2003-2011: US$264.5 million

*Ratio: % global arable land / % global population

The adoption of biotech maize in the Philippines has increased consistently every year since it was first commercialized in 2003. The area planted to biotech maize was projected to significantly increase in the wet and dry seasons in 2012 to reach 750,000 hectares, up 16% from the 644,000 hectares of biotech maize in 2011 (Figure 29). Notably, the area occupied by the stacked traits of Bt/HT maize has continuously increased every year reaching 675,000 hectares in 2012, compared with only 545,000 hectares in 2011, up by a substantial 24%, reflecting the preference of farmers for stacked traits and the superior benefits they offer over single trait. This shift in farmers' preference from single trait maize to those with combined traits has been observed since the introduction of stacked-traits in 2006. The total hectarage planted to the single trait Bt maize, after experiencing a 32% decline between 2008 to 2009 and a 12% decline between 2009 and 2010, has further decreased by 76% in 2012, with a total of only 3,000 hectares compared to last year's 12,300 hectares. Single trait herbicide tolerant (HT) maize was planted on 72,000 hectares in 2012, which is only 9.6% of the total biotech maize hectarage compared to last

Figure 29. Increase in Hectarage of Biotech Maize in the Philippines and Proportion of Commercialized Traits, 2003 to 2012



Source: Compiled by ISAAA, 2012.

year's 13.4%. On a percentage basis, biotech yellow maize has consistently increased by about 5% of the total yellow maize hectarage every single year from the first year of commercialization in 2003, reaching the highest ever level of 59% in 2012 (up from 51% in 2011). Consistent with the experience of other biotech maize growing countries the year-by-year steady increase in adoption of biotech maize reflects the significant and consistent benefits generated by biotech maize to farmers in the Philippines.

The number of small resource-poor farmers, growing on average 2 hectares of biotech maize in the Philippines in 2012, was estimated at 375,000 up significantly by 53,000 from 322,000 in 2011.

A total of eight events of biotech maize are approved for commercial planting in the Philippines: MON810 for insect resistance (first approved in 2002 and the approval was renewed in 2007), NK603 for herbicide tolerance (first approved in 2005 and renewed in 2010), Bt11 for insect resistance (first approved in 2005 and renewed in 2010), GA21 for herbicide tolerance approved in 2009, the stacked gene product of MON810/NK603 (first approved in 2005 and renewed in 2010), the stacked trait Bt11/GA21 for insect resistance and herbicide tolerance approved in 2010, MON89034 which contains two Bt genes for resistance to fall armyworm, black cutworm, the ECB and the corn worm, and the stacked trait IR/HT, MON89034 x NK603 (Table 29). In addition, a total of 27 stacked trait maize and cotton products have been approved for importation for direct use as food, feed and for processing, from among a total of 64 biotech crops and products currently approved for direct use as food, feed and for processing.

The future acceptance prospects for biotech crops in the Philippines continue to look promising with new biotech crop products also being developed by national and international institutes. Among these are Golden Rice (GR), a biofortified rice being developed by the Philippine Rice Research Institute (PhilRice) and the International Rice Research Institute (IRRI). The first generation Golden Rice was first tested in advanced field trials in IRRI in 2008, and second generation of Golden Rice (GR2) introgressed into selected mega varieties were field tested in the wet season of 2010. At PhilRice, confined field trials of advanced GR2 introgressed lines were conducted in February to June 2011. In March 2012, four multilocational trials were started to evaluate the agronomic and product performance under Philippine field conditions; to produce grains and other plant materials that will be used for the various tests required to complete the biosafety data requirements; to obtain data for environmental biosafety assessment; and to produce grains that will be used for a nutritional study to be conducted, if Golden Rice receives biosafety approval from the Philippines. Agronomic data have been collected and samples for compositional analysis are being tested in various laboratories in the Philippines. Data analysis on various parameters is either ongoing or yet to be conducted based on data availability. The required second season multilocational trial has just been started in all four sites. It is expected that regulatory data required for the approval for Golden

Table 29. Approval of Biotech Maize Events in the Philippines, 2002 to 2011

Crop	Event	Trait	Year of Approval/Renewal
Maize	MON810	IR	2002/2007
Maize	NK603	HT	2005/2010
Maize	Bt11	IR	2005/2010
Maize	MON810 x NK603	IR/HT	2005/2010
Maize	GA21	HT	2009
Maize	Bt11/GA21	IR/HT	2010
Maize	MON89034	IR/HT	2010
Maize	MON89034 x NK603	IR/HT	2011

IR: Insect resistance, HT: Herbicide Tolerance
Source: Compiled by ISAAA, 2012.

Rice commercialization be completed by 2013. Another research effort by the PhilRice scientists is to develop the '3-in-1' rice which incorporates resistance to tungro virus and to bacterial blight disease in Pro-Vitamin A-enriched lines (Antonio A. Alfonso, Personal Communications).

The fruit and shoot borer resistant eggplant being developed by the Institute of Plant Breeding (IPB), University of the Philippines Los Baños (IPB-UPLB) already completed in 2011 the first two seasons of multi-location field trials in the island of Luzon. Additional trials were continued in 2012 both for hybrids and open pollinated varieties which generated additional regulatory data. Biotech papaya with delayed ripening and papaya ring spot virus (PRSV) resistance, also being developed by IPB-UPLB, has already been tested in confined field trials in 2012. Bt cotton for the first time was tested in a confined field trial in 2010 and has started multi location field trials in 2012. Initiatives in other crops include the development of a virus resistant sweet potato through collaborative activities between the Visayas State University (VSU) and IPB-UPLB and the initial efforts to generate transgenic lines of virus resistant abaca (*Musa textilis*) by the Fiber Industry Development Authority (FIDA) in collaboration with the University of the Philippines. The Philippine Department of Agriculture Biotechnology Program Office and the Department of Science and Technology have been very supportive of research and development activities on biotech crops and have been eager to support the products that will emerge from the R&D pipeline for commercialization in the near term.

It is important to note that the Philippines is the first country in the ASEAN region to implement a regulatory system for transgenic crops; the system has also served as a model for other countries in the region and other developing countries outside Asia. The Philippine biotechnology regulatory system was formalized with the issuance of Executive Order No. 430 in 1990 establishing the National Committee on Biosafety of the Philippines (NCBP). In 2002, the Department of Agriculture (DA) issued Administrative Order No. 8, which provided the basis for commercial release of biotech crops. Subsequently, in 2006 Executive Order 514 was issued further strengthening the NCBP and establishing the National Biosafety Framework. In 2008, the country launched its national biosafety clearinghouse, BCH Pilipinas, to serve as the Philippine node of the Biosafety Clearing House (BCH) mechanism established under the Cartagena Protocol on Biosafety (CPB). The Philippines, which grows approximately 2.5 million hectares of maize is still the only country in Asia to approve and grow a major biotech feed crop; moreover, the Philippines achieved a biotech mega-country status with biotech maize in 2004, i.e. 50,000 hectares or more. Asia grows 32% of the global 158 million hectares of maize with China itself growing 29 million hectares, plus significant production in India (7.8 million hectares), Indonesia (3.6 million hectares), Philippines (2.7 million hectares), and Vietnam, Pakistan and Thailand (each with about 1 million hectares) (FAO, 2009).

In May 2012, a petition was filed by Greenpeace and other environmentalists and politicians to the Supreme Court calling for the imposition of the Writ of Kalikasan and issuance of a Temporary Environmental Protection Order (TEPO) against the conduct of the Bt eggplant field trials. The respondents include the Department of Environment and Natural Resources, University of the Philippines Los Baños, UPLB Foundation, ISAAA, University of the Philippines Mindanao, Bureau of Plant Industry, and Fertilizer and Pesticide Authority. The petition was forwarded by the Supreme Court to the Court of Appeals who in turn requested the petitioners and respondents to provide information and papers to counter or support the petition. The respondents jointly filed to the Court of Appeals five arguments against the petition: 1) the petition is moot and academic; 2) the petition presents no justifiable controversy; 3) petitioners have no legal standing to institute the petition; 4) the petition should be dismissed for failure to observe the doctrines of hierarchy of courts, exhaustion of administrative remedies and primary jurisdiction; and 5) Bt eggplant field testing is not covered by the Philippine Environmental Impact Statement System and Sections 26 and 27 of the Local Government Code. As of this writing, no TEPO has been issued by the Court. The multilocational field trials of Bt eggplant under the current permit has been completed with all biosafety data completely gathered in all trial site.

Benefits from Biotech Crops in the Philippines

The benefits of biotech maize to Filipino farmers' livelihood, income, the environment and health have been well studied and documented. Farms planted with Bt maize in the Northern Philippine provinces have significantly higher populations of beneficial insects such as flower bugs, beetles, and spiders than those planted with conventional hybrid maize (Javier et al. 2004).

The farm level economic benefit of planting biotech maize in the Philippines in the period 2003 to 2011 is estimated to have reached US$264.5 million. For 2011 alone, the net national impact of biotech maize on farm income was estimated at US$93.6 million (Brookes and Barfoot, 2013, Forthcoming).

Other studies report that gain in profit at the farmer level was computed at 10,132 pesos (about US$180) per hectare for farmers planting Bt maize with a corresponding savings of 168 pesos (about US$3) per hectare in insecticide costs (Yorobe and Quicoy, 2006). In another socio-economic impact study (Gonzales, 2005), it was reported that the additional farm income from Bt maize was 7,482 pesos (about US$135) per hectare during the dry season and 7,080 pesos (about US$125) per hectare during the wet season of the 2003-2004 crop year. Using data from the 2004-2005 crop year, it was determined that Bt maize could provide an overall income advantage that ranged from 5 to 14% during the wet season and 20 to 48% during the dry season (Gonzales, 2007). In a more recent study covering crop year 2007-2008, biotech maize increased average net profitability in 9 provinces by 4 to 7% during the wet season and 3 to 9% during the dry season (Gonzales, 2009). Overall, the four studies that examined net farm income, as well as other indicators, consistently confirmed the positive impact of Bt maize on small and resource-poor farmers and maize producers generally in the Philippines.

The projected benefits from other biotech crops nearing commercialization, such as the Golden Rice could be higher than maize at US$88 million per year (Zimmermann and Qaim, 2004), while benefits from Bt eggplant are projected at almost 9 million pesos (about US$200,000, Francisco, 2007). The benefits from Golden Rice are derived from gains due to reduced mortality and reduced disability. Benefits from Bt eggplant include higher income from higher marketable yields, reduction in insecticide use by as much as 48%, and environmental benefits associated with less insecticide residue in soil and water, and the protection of beneficial insects and avian species. Bt eggplant adoption could result to savings of about 2.5 million pesos (about US$44,414) in human health costs, and 6.8 million pesos (about US$120,805) in aggregated projected benefits for farm animals, beneficial insects, and avian species (Francisco, 2009). For the virus resistant papaya, a substantial increase in the farmer's net income is projected, with expected returns of up to 275% more than conventional papaya (Yorobe, 2006).

Other recently completed ex-ante studies in Bt cotton and abaca (*Musa textilis*) indicate significant potential social and economic benefits. These studies were conducted to assist Philippine policy makers decide whether the development and commercialization of these biotech crops in the country is a sound investment. Chupungco et al. (2008) has concluded that Bt cotton commercialization in the Philippines will improve yield by about 20% with a return on investment (ROI) of 60-80%, compared to 7-21% when using conventional varieties. The biotech abaca resistant to abaca bunchy top virus (ABTV), abaca mosaic virus (AbaMV) and bract mosaic virus (BrMV), were estimated to be able to provide an additional increase in yield of 2.5 tons per hectare and 49.36% ROI after 10 years (Dumayas et al. 2008).

In summary, the Philippines has already gained US$264 million from biotech maize in a short span of nine years, 2003 to 2011, and is advancing the adoption of the maize stacked traits, IR/HT. In 2012, stacked traits in maize represented around 85% of the total biotech maize area in the Philippines. Future prospects look encouraging, with "home grown" biotech products likely to be commercialized in the next 3 years including Bt eggplant in 2012/13 and with a reasonable possibility that the Philippines might also be the first country to commercialize Golden Rice around 2013-14 (IRRI, 2012).

Support from Stakeholders

Dr. Emil Q. Javier, President of the National Academy of Science and Technology (NAST), in his welcome message during the launch of ISAAA Brief 43 in February 7, 2012, highlighted the significant developments of biotechnology in the country through government efforts. ***"So we look forward to making continuing progress to modernize our agriculture by way of applications of modern biotechnology…and finally having Golden Rice served on our tables; we look forward to Bt eggplant similarly getting to our tables, and of course the papaya ringspot virus resistant papaya,"*** he said.

In the same forum, Agriculture Undersecretary for Policy and Planning Segfredo Serrano also shared experiences from a decade of biotech commercialization in the Philippines. Usec Serrano said that ***"the very interest of the Department of Agriculture on modern biotechnology stems from the very nature of Philippine agriculture which is archipelagic, lacks vast land areas, and the various environment that needs to be dealt with on the development of a technology. There is thus the need to'exploit the resources of the mind', the output of which is the technology, and the need for the ability of the farming population or the stakeholders to utilize and benefit from the technology"*** (Crop Biotech Update, 10 February, 2012).

In a message to employees of the National Institute of Molecular Biology and Biotechnology at the University of the Philippines Los Baños (BIOTECH-UPLB), Department of Science and Technology Secretary Mario Montejo identified biotechnology as one of the 'vital' fields of sciences for the country's development. Department of Agriculture (DA) Undersecretary for Policy and Planning Segfredo Serrano noted that the country must exploit the ability of people in generating local technologies so as to address challenges in food security and effects of climate change. He also encouraged the university to be more active in its research and development efforts (Crop Biotech Update, 17 February, 2012).

On April 3, 2012, DA Secretary Proceso Alcala's message was read to the attendees celebrating the ten year anniversary of the issuance of the Department of Agriculture Administrative Order No. 8, which regulates GM crop commercialization in the Philippines. He acknowledged and lauded the economic and environmental benefits brought by biotech corn in its almost 10 years of commercialization in the country. He said that the corn industry would not have the additional eight billion peso profit in the corn sector without biotech corn and that about 400,000 Filipino corn farmers have benefited from this technology. The secretary also reiterated that biosafety regulation in the country is based on international standards.

In the same occasion, Dr. Candida Adalla, Chair of the DA Biotechnology Program Office, said that because of the consistent biotech policies implemented in the country, agriculture is continuously growing with significant contributions from biotech crops (Crop Biotech Update, 4 April 2012).

Several esteemed scientists in the Philippines emphasized the need for an alternative to excessive pesticide spraying in eggplant. Dr. Emiliana Bernardo, entomologist and member of Scientific and Technical Review Panel (STRP) of the Department of Agriculture, said that the current practice of spraying in eggplant farms calls for a healthier and more environment-friendly option. ***"The very basic question is 'which is safer?' The present practice or the alternative, the Bt eggplant which is rigorously evaluated by experts? Is bathing the unharvested eggplant fruits in chemicals, which would end up in dinner tables of people, safe?"*** said Dr. Bernardo, who is also a member of the Institutional Biosafety Committee of the University of the Philippines Los Baños (UPLB) for the multi-location field trial in the university. ***"UPLB is conducting research on Bt eggplant because we know that this has promising potentials and is considered safer than the current practice,"*** she said.

Similarly, National Academy of Science and Technology (NAST) Academician Dr. Ruben L. Villareal said that Bt crops that can resist infestation of specific insect pests are among those prioritized, especially when insect control using conventional means are ineffective and costly. "***Based on my experience as a vegetable breeder, there is no existing source of eggplant germplasm that is highly resistant to the fruit and shoot borer. Biotechnology is a tool that could develop varieties that would be advantageous to farmers, consumers and the environment. We are actually very fortunate that the technology is available,"*** said Dr. Villareal (Crop Biotech Update, 11 May 2012).

Congressman Angelo Palmones defended the need to conduct the multi-location field trials of the fruit and shoot borer resistant Bt eggplant after he witnessed the harvesting operations in the trial site at the University of Southern Mindanao (USM), Kabacan, North Cotabato last June 29, 2012. Palmones said that ***"Bt eggplant would not only promote balance in the environment, but would also serve as a national agricultural advantage through quality and lesser chemical-laden crops produced by healthy farmers. Once Bt eggplant is commercialized, the product can be exported to countries with strict plant quarantine regulations, especially on the presence of chemical residues."*** On the Writ of Environment filed by an anti-GMO group against the Bt eggplant multi-location field trials, Palmones said that he is opposed to the petition because the Bt eggplant project is a legitimate research. ***"It does not bring any harm to people. If we stop this kind of research, we will never move or develop as a country in using modern technologies and if that would be our mindset, we would be left behind, especially our farmers,"*** he said (Crop Biotech Update, 6 July 2012).

"Modern biotechnology is for skillful, ingenious, and progressive farmers," was the key message of Dr. Candida Adalla, director of the Department of Agriculture's (DA) Biotechnology Program, to the Filipino farmers during the 3rd National Agricultural Biotechnology Farmers Conference in Davao City last 26 September 2012. Dr. Adalla assured the safety of genetically modified (GM) crops which underwent rigorous and extensive study with enormous investment (Crop Biotech Update, 3 October, 2012).

Brief Chronological Overview of crop biotech related events in the Philippines in 2012 reported in ISAAA's weekly Crop Biotech Update (CBU), where original reference is provided:

1. The Philippine Genome Center (PGC) was launched in November 2011 at the University of the Philippines Diliman. Health, agriculture, biodiversity for drug discovery and bio-energy, forensics and ethnicity, and ethical, legal, and social issues associated with genomics research are the priority areas of PGC (Crop Biotech Update, 2 December, 2012).

2. Asian corn borer (ACB) pest populations in the Philippines continue to be susceptible to the insect resistant Bt corn, after almost ten years of Bt corn adoption, reported Dr. Edwin Alcantara, University Researcher at the National Institute of Molecular Biology and Biotechnology - University of the Philippines Los Baños (BIOTECH-UPLB) (Crop Biotech Update, 23 March, 2012).

3. Peer and kinship systems facilitate the adoption and uptake pathways of biotech corn in some provinces of the Philippines, according to a study by the University of the Philippines Los Baños. The researchers noted the changes in the lives of farmers after adoption which includes increase in yield and income (Crop Biotech Update, 20 April, 2012).

4. Farmers from Pakistan who visited the Philippines for the Pan-Asia Farmers Exchange Program were impressed with the biotech corn adoption in the Philippines. "We (farmers) did not have much knowledge about biotech crops earlier but now, after practically seeing the biotech crop fields and meeting the scientists as well as farmers in the Philippines, we have learned a lot about biotechnology," said Zafar Hayat, a farmer member of Farmer Associates Pakistan (Crop Biotech Update, 25 May 2012).

5. According to the update report of the International Rice Research Institute (IRRI), Golden Rice is still under development and evaluation as of September, 2012. It will only be made available broadly to farmers and consumers if it is approved by national regulators and proved to reduce vitamin A deficiency in community conditions– a process that is likely to take another two to three years (Crop Biotech Update, 19 September, 2012).

6. Philippines' National Corn Program Director Edilberto de Luna announced that the country has the capacity to export as much as 100 tons of corn at any given time. He also said that members of the interagency committee are now reviewing the appeal of the Philippine Maize Federation, Inc. (PhilMaize) to export corn to drought stricken countries such as the United States that lack corn supply (Crop Biotech Update, 5 September, 2012).

Farmers' Views on Planting Biotech Maize for the ISAAA-commissioned study Adoption and Uptake Pathways of Biotechnology Crops: The Case of Biotech Corn Farmers in Selected Provinces of Luzon, Philippines (Torres et al. 2012).

Gertrudez Cerezo (San Jacinto, Pangasinan):
"Most farmers agree that biotech maize is easy to plant since the pesticide is already in the plant. In addition, biotech maize grows fast and it can tolerate herbicide so once the field is sprayed, it will still grow. Once biotech maize is planted and watered, farmers can look for other jobs and livelihood, so biotech maize is very good."

Dante Apostol (Reina Mercedes, Isabela):
"When I planted biotech maize, my income increased so I was able to raise the down payment to buy me a motorbicyle and side car, which provided additional income for my family. This is why I think biotech maize is a good technology not only for me but for other farmers... We gain more income from biotech maize because of high yield, reduced insecticide and herbicide use. When we plant conventional maize, expenses from weeding and cleaning of the field three to four times until harvest is too high."

Rosalie Ellasus (San Jacinto, Pangasinan):
"When I planted biotech corn, which does not need frequent insecticide spray because they are not attacked anymore, I do not frequent the field as much. Thus, when it comes to biotech corn, I don't need to worry about pest anymore and this gives me a piece of mind."

Roman Santos Sr. (Naguilian, Isabela):
"In the beginning, I was not keen on planting biotech corn, since I am used to planting the native corn. But when I saw that my neighbors are harvesting a lot and gaining, I was encouraged and motivated to plant biotech corn too."

AUSTRALIA

Australia grew 688,000 hectares of biotech crops in 2012, comprising 512,000 hectares of biotech cotton, (down from 597,000 hectares in 2011 and 520,000 hectares in 2010), plus 176,000 hectares of biotech canola (up from 139,000 in 2011 compared with more than a quadruple increase from the 41,200 biotech canola hectares in 2009). A remarkable 99.5% of all the cotton grown in Australia in 2012 was biotech and 95% of it featured the stacked genes for insect resistance and herbicide tolerance. The total

biotech crop hectarage in 2012 represents a ~15-fold increase over the 48,000 hectares of biotech crops in 2007 during which Australia suffered a very severe drought which continued in 2008 and to a lesser degree in 2009 when the country was still recovering from the multi-year drought which is the worse on record in Australia. Enhanced farm income from biotech crops is estimated at US$607 million for the period 1996 to 2011 and the benefits for 2011 alone at US$188.3 million.

AUSTRALIA

Population: 21.0 million

GDP: US$1,015 billion

GDP per Capita: US$47,370

Agriculture as % GDP: 3%

Agricultural GDP: US$30.6 billion

% employed in agriculture: 3%

Arable Land (AL): 46.1 million hectares

Ratio of AL/Population*: 10.0

Major crops:
- Wheat
- Barley
- Sugarcane
- Fruits
- Cotton

Commercialized Biotech Crops:
- Bt/Bt-HT Cotton
- FC Carnation
- HT Canola

Total area under biotech crops and (%) increase in 2012:
688,000 Hectares (0)

Farm income gain from biotech, 1996-2011: US$607 million

*Ratio: % global arable land / % global population

In 2012, Australia grew 688,000 hectares of biotech crops, (down 10% from 736,000 hectares planted in 2011) comprising 512,000 hectares of biotech cotton, (down from 597,000 hectares in 2011 and 520,000 hectares in 2010), plus 176,000 hectares of biotech canola (up 25% from 139,000 in 2011). This compares with more than a four-fold increase from the 41,200 biotech canola hectares in 2009 to 133,000 hectares in 2010. The decrease in biotech cotton was due to decreased plantings and lower cotton prices. A remarkable 99.5% of all the cotton grown in Australia in 2011 was biotech and 95% of it featured the stacked genes for insect resistance and herbicide tolerance. Biotech cotton hectares in 2012 comprised, 493,000 hectares of Bt/HT and 19,000 hectares of HT.

The total biotech crop hectarage of 688,000 hectares in 2012 represents a ~15-fold increase over the 48,000 hectares of biotech crops in 2007 during which Australia suffered a very severe drought which continued in 2008 and to a lesser degree in 2009 when the country was still recovering from the multi-year drought which is the worse on record in Australia. In 2012, Australia, for the fifth year, grew herbicide tolerant RR®canola in three states: New South Wales (NSW), Victoria and with Western Australia joining for the third time. According to the Australian Oilseeds Federation, an estimated 1.8 million hectares of canola were grown in Australia in 2012 of which 176,000 hectares, equivalent to 10% of the national total, were grown in the three states of Western Australia, NSW and Victoria. Western Australia grew an estimated 125,000 hectares of canola in 2012, Victoria grew an estimated 15,650 hectares and New South Wales an estimated 35,000 hectares. Nationally, this is a significant increase of 27% over the 139,150 hectares grown in 2011.

Drought Tolerant Wheat

In Australia, the Office of the Gene Technology Regulator (OGTR) oversees and regulates the conduct of field trials. The office assesses individual field trial applications and once approved issues a license under which it can be conducted. Biotech researches on wheat gene technology are undertaken by public research entities that include Commonwealth Scientific and Industrial Organization (CSIRO), University of Adelaide and Victorian Department of Primary Industries in partnership with international companies. The Australia biotech wheat research can be grouped into two main categories based on the target clientele. For growers, wheat is being improved for agronomic performance such as the development of plants with greater ability to survive and thrive in heat/drought conditions and cope with climate change. For consumers, research is on altering grain composition such as developing foods that have the potential to address diabetes, heart disease and other illnesses.

There are 10 Biotech wheat research project field trial licenses approved in Australia from 2007 to 2012 that include: improved tolerance to drought and other abiotic stresses, improved ability to utilize nutrients, increased dietary fiber and different grain compositions – including characteristics for bread making and human nutrition value. Currently, biotech wheat is at least seven to ten years away from the marketplace. Prior to commercialization, biotech wheat varieties will have to undergo a thorough assessment from Australia’s regulatory authorities including the OGTR and Food Standards Australia New Zealand (FSANZ). It will be comprehensively assessed for human health and environmental safety. Alongside this timeframe, the Australian grains industry will work to address market and trade considerations, just as it does with all new crops (Agrifood Awareness Australia, 2010).

Each field trial is limited in size and duration, ranging in size from 0.1 to 2.3 hectares per year for up to 5 years. The trials are subject to strict containment conditions to manage the potential for spread and persistence of the biotech wheat and the introduced genes in the environment. The OGTR actively inspects trials for compliance with license conditions. There have been no breaches of containment with any of these field trials. Biotech wheat from these trials is not permitted to enter the commercial human food or animal feed. Three licenses held by CSIRO authorize animal nutritional studies (DIR 092, DIR 093, and DIR 111); two of these also authorize experimental human nutritional studies (DIR 093 and DIR 111). These studies are also subject to approval by animal and human ethics committees, and would use products made from biotech wheat with altered grain composition aimed at improving nutritional properties such as glycemic index (OGTR Fact Sheet, 2012).

Biotech Sugarcane

Biotech sugarcane is not yet grown commercially in Australia, however, the OGTR has issued several licenses for field trials of these crops. Biotech sugarcane is being studied for traits such as herbicide tolerance, altered plant growth, enhanced drought tolerance, enhanced nitrogen use efficiency, altered sucrose accumulation and improved cellulosic ethanol production from sugarcane biomass. Trials are currently being conducted in Queensland (GM Wheat and Sugarcane in Australia, 2012).

Biotech Banana

Cavendish and Lady Finger bananas have been genetically modified to resist Fusarium wilt or Panama disease. The field trial is being conducted by the Queensland University of Technology led by Dr. James Dale in Litchfield Municipality, Northern Territory on a maximum area of 1.5 ha from November 2010 to 2014 (OGTR, 2012). Panama disease race 1 has wiped out banana variety Gros Michel in the 1950s and 60s. Gold finger, an African banana variety resistant to Race 4 of the Fusarium pathogen also was short lived. The current field trial of these two biotech bananas is hoped to put an end to the devastating disease. Other on-going researches on bananas include resistance to black sigatoka and bunchy top (ABC Rural, 2010).

Simultaneously, Dr. Dale also received a support grant for the provitamin A-enriched banana from the Bill and Melinda Gates Foundation. A field testing for banana varieties Williams and Dwarf Cavendish, and LadyFinger hybrid with increased level of pro-vitamin A and/or iron and marker gene expression was approved in February 2011 and is being conducted in May 2011 to May 2013. Philanthrophist Bill Gates and his family visited the field trial site where they observed bananas with 15 times the amount of beta carotene, a big improvement from the initial target of four-fold increase. The technology has been transferred to Ugandan research partners at the national Agricultural Research Organization of Uganda where the bananas are also under field trial (Fresh Plaza, 2012).

Biotech Canola

Biotech canola offers Australia a way to increase yield in a sustainable manner and generating higher profits for farmers and a more affordable product for consumers who are not prepared to pay a premium for conventional canola. In the past 10 years, Canada has successfully produced and marketed the equivalent of 50 years of conventional canola in Australia which has missed out on significant domestic and export opportunities with biotech canola (Australian Ministry of Agriculture, Fisheries and Forestry Press Release, 2007). The guidance for Australia, which operates the best managed biotech cotton program in the world, is to take the experience with biotech cotton, apply it to correct the mistakes of late commercialization of biotech canola and apply the learnings from both crops to prepare in advance for the successful, and timely introduction of biotech wheat, which is judged to be inevitable in the longer term – wheat is Australia's most important crop and significant export.

Benefits from Biotech Crops in Australia

Australia is estimated to have enhanced farm income from biotech cotton by US$607 million in the period 1996 to 2011 and the benefits for 2011 alone is estimated at US$188 million (Brookes and Barfoot 2013, Forthcoming). The results of a federal study released in September 2005 by the Australian Bureau of Agricultural and Resource Economics (ABARE), Apted et al. (2005) is consistent with the views of some farmers, and estimates that a ban on biotech canola in Australia over 10 years could have cost Australian farmers US$3 billion.

Brief Chronological Overview of crop biotech related events in Australia in 2012 reported in ISAAA's weekly Crop Biotech Update (CBU), where original reference is provided:

1. The Commonwealth Scientific and Industrial Research Organization (CSIRO) and the Cotton Seed Distributors (CSD) renewed their cotton joint project for another five years which focus on improved quality, higher yields, drought and heat tolerance, water use efficiency and pest and disease resistance (Crop Biotech Update, 16 March 2012).

2. University of Melbourne Professors Richard Roush and David Tribe published a commentary which enumerated the benefits of modern agriculture in Australia that includes reduction in carbon emissions, prevents soil erosion, and minimizes environmental damage by herbicides and pesticides due to run-off into river systems – a success made when Australia's cotton growers switched to genetically modified (GM) cotton 15 years ago (Crop Biotech Update, 15 June 2012).

Scientists and Farmers Support Biotech Crops in Australia

Delegates at the 2008 ABARE conference learned that the introduction of GM crops in Australia were creating both opportunities and challenges for farmers:

Australia's former Chief Scientist, Dr. Jim Peacock, said biotechnology will play an important role in addressing global issues of food security. ***"We lose 12 percent of yields around the world to disease pathogens, and GM technologies offer a means to increase global food supply,"*** Dr. Peacock said.

ABARE Principal **Research Economist Max Foster** said that evidence of separate markets for GM and non-GM grains is already present in world markets. **"World trade in soybeans, corn, canola and cotton is dominated by GM varieties, but non-GM crop varieties coexist as niche markets,"** Mr. Foster said.

Victorian canola grower Andrew Broad told the conference that biotechnology will play a significant role in the Australian grain industry remaining competitive, with declining yields and profitability from canola becoming significant issues. ***"Without biotechnology, the Australian canola industry will not remain viable,"*** Mr. Broad said.

GM canola grower Reuben Cheesman from St. Arnaud in Victoria grew 56 hectares of Roundup Ready canola last year and is increasing this to 180 hectares this year. ***"Lower herbicide costs and the ease of use of the system were true benefits. Together with higher yields, oil content and superior weed control in comparison to Clearfield® varieties, Roundup Ready has a distinct advantage over other systems,"*** he said.

Views on Biotech Crops in Australia

The motion to disallow GM Crops by the Green Parties in Western Australia (WA) was voted down by the Nationals and Liberals in the State Parliament in May 2010. On this, **Mike Norton, the WA president** was not surprised that this move was defeated in the upper house of the Parliament. He said that the use of GM technology is well and truly warranted. ***"I think the bulk of farmers would certainly hope that GM technology is well and truly here to stay. It's certainly another tool that Western Australian farmers need to manage their operations without increasing costs"*** (Norton, 2010).

Mr. Roy Hamilton is a founding member of the Riverine Plains Grower Group, and a regular participant in Grain Research and Development Corporation (GRDC) Southern Grower Updates. Mr. Hamilton also sits on the SE Regional Advisory Committee and enjoys reflecting local farmer issues and priorities through to the GRDC Southern Panel. ***"I like looking at new ways of doing things. I was in Canada in 2001 and did some research and talked to a lot of farmers and became quite comfortable with the science and technology, and the rigour involved in the safety of the GM system,"*** Mr. Hamilton said (Hamilton, 2010).

Dr. Jason Clay, senior vice president at the World Wildlife Fund (WWF) said of the increase in world's population, ***"we need to address this because the 'impacts' to people and food production/consumption have on the land and water that are acceptable today with 6.8 billion people will not be acceptable with 9.1 billion people. We will have to get better at producing more food with fewer resources."*** Agriculture/food producers need to become increasingly more efficient and producers must adopt advanced genetics, management practices and technology and emphasized that ***"we cannot abandon modern genetics and technology,"*** he added (Clay, 2010).

BURKINA FASO

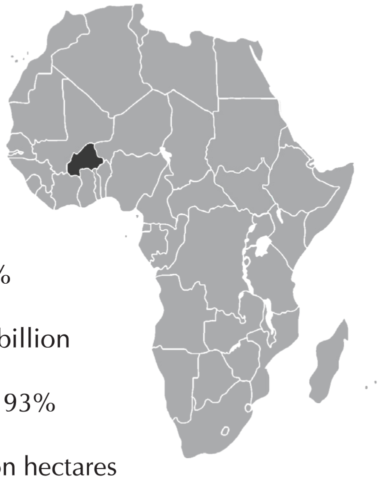
2012 was the fifth year for farmers in Burkina Faso to benefit significantly from Bt cotton. Out of a total of 615,796 hectares planted to cotton in the country in 2012, 313,781 hectares or 51% were planted to Bt cotton (BGII). Total cotton planted in 2012 was 615,795 hectares compared with 424,810 hectares in 2011, equivalent to a 45% increase over 2011. The record biotech cotton hectarage increased by 27% in 2012 from 247,000 hectares in 2011 to 313,781 hectares in 2012. Based on an average cotton holding of 3.16 hectares the number of farmers growing Bt cotton in 2012 was approximately 100,000. The increase in total cotton area of 190,986 hectares (a 45% increase) from 424,810 in 2011 to 615,796 in 2012 was principally due to the fact that success with Bt cotton and the benefits that it offers has provided the incentive for Burkina Faso farmers to increase plantings of Bt cotton. The total area planted to cotton increased in Burkina Faso in 2012 despite the fact that global hectares of cotton was down significantly by 10 to 15%.

The fact that 51% of cotton plantings were biotech cotton in 2012, clearly demonstrates that Bt cotton in Burkina Faso continues to offer substantial benefits to farmers. The latest data on benefits from Bt cotton in 2011 includes an average yield increase of almost 20%, (19.7%) plus labor and insecticide savings (2 rather than 6 sprays), which resulted in a net gain of about US$95.35 per hectare compared with conventional cotton.

It is estimated that Bt cotton has the potential to generate an economic benefit of up to US$70 million per year for Burkina Faso. National benefits to Bt cotton farmers in 2011 were estimated at US$26 million representing 67% of total benefits with the balance accruing to the technology developers. Extrapolating from 2011 data, the national benefit from Bt cotton in 2012 was about US$30 million. This is a significant achievement for a country with a per capita GDP of ~US$500 per year. Thus, in summary, plantings of Bt cotton in Burkina Faso has increased from 9,000 hectares in 2008, 116,000 hectares in 2009, 260,000 hectares in 2010, 247,000 hectares in 2011 and to a record 314,000 (313,761) hectares in 2012. In 2011, the average increase

in yield for Bt cotton was 19.7% over conventional and insecticide sprays were reduced from 6 to 2. Profit increased by 50% to an average of US$95.35 per hectare and benefits were consistent across farm types and geographical zones. Bt cotton farmers captured 53% of the total benefits in 2009, 66% in 2010 and 67% in 2011 and there is no reason to believe that 2012 will be different.

BURKINA FASO



Population: 15.8 million

GDP: US$8.1 billion

GDP per Capita: US$510

Agriculture as % GDP: 28%

Agricultural GDP: US$2.3 billion

% employed in agriculture: 93%

Arable Land (AL): 5.2 million hectares

Ratio of AL/Population*: 1.5

Major crops:

- Cotton
- Millet
- Peanuts
- Maize
- Sorghum
- Rice
- Shea nuts

Commercialized Biotech Crops: Bt Cotton

Total area under biotech crops and (%) increase in 2011:
313,781 Hectares (27%)

Farm income gain from biotech, 2009-2011: US$70 million

*Ratio: % global arable land / % global population

Cotton remains Burkina Faso's principal cash crop generating over US$300 million in annual revenues. This represents over 60% of the country's export earnings (ICAC, 2006). Exports of cotton have ranged from 775,000 bales per year to 1.4 million bales. In the absence of effective plant protection, insect pests can result in yield losses of 15% to 35% valued at US$18 to US$40 million annually. Some 2.2 million people depend directly or indirectly on cotton, often referred to locally as "white gold" (Vognan et al. 2002), "the king" (CARITAS, 2004; Elbehri and MacDonald, 2004) and "the foundation" of rural economies. Increasing productivity by controlling insect pests in cotton can directly translate into a significant boost in GDP. Other commercial crops for export include fruits, vegetables, French beans and tomatoes. It is estimated that Bt cotton has the potential to generate an economic benefit of up to US$70 million per year for Burkina Faso, based on yield increases of 20%, plus a two-thirds reduction in insecticides sprays, from a total of 6 sprays required for conventional cotton, to only 2 for Bt cotton.

The potential economic impacts of insect resistant (Bollgard®II) cotton in Burkina Faso are significant. Even with the application of recommended insecticides, crop losses of 30% or more due to insect pests of cotton have been recorded (Goze et al. 2003; Vaissayre and Cauquil, 2000). On average, at the national level, the annual cost for insecticides for the control of cotton bollworms and related pests is US$60 million per year (Toe, 2003). However, insecticides are proving ineffective with losses due to bollworm as high as 40% even with the full treatment of insecticides (Traoré et al. 2006). Moreover, Bt cotton may prove to be the only option in areas where pest infestations are so high that growing conventional cotton with insecticides is unprofitable. Adoption of Bt cotton is thus inspired by the need to improve productivity, raise farmers' incomes and reduce pesticide use. In 2009 alone, 650,000 tons were harvested depending on climatic conditions.

Insect pests and drought are the two significant constraints to increased productivity in the country. All the cotton is produced by small resource-poor subsistence farmers, similar to the situation in countries like China and India. Yield is however low at approximately 367 kg per hectare, compared with 985 kg per hectare in the USA (Korves, 2008). In an effort to address the challenge posed by insect pests, the national research institute, Institut de l'Environnement et de Recherches Agricoles (INERA), field tested Bt cotton over a four-year period (2003 to 2007) with excellent results. INERA scientists in collaboration with Monsanto incorporated the Bt gene (Bollgard®II) into selected popular cotton varieties that are well adapted to the local environment. After rigorous risk assessment and stakeholder consultations, the National Bio-Security Agency approved two varieties of Bt cotton for seed production and commercialization.

2012 was the fifth year for farmers in Burkina Faso to benefit significantly from Bt cotton. Out of a total of 615,796 hectares planted to cotton in the country in 2012, 313,781 hectares or 51% were planted to Bt cotton (BGII). Total cotton planted in 2012 was 615,795 hectares compared with 424,810 hectares in 2011, equivalent to a 45% increase over 2011. The record biotech cotton hectarage increased by 27% in 2012 from 247,000 hectares in 2011 to 313,781 hectares in 2012. Based on an average cotton holding of 3.16 hectares the number of farmers growing Bt cotton in 2012 was approximately 100,000. The increase in total cotton area of 190,986 hectares (a 45% increase) from 424,810 in 2011 to 615,796 in 2012 was principally due to the fact that success with Bt cotton, and the benefits from Bt cotton has provided the incentive for Burkina Faso farmers to increase plantings of Bt cotton. The total area planted to cotton increased in Burkina Faso in 2012 despite the fact that global hectares of cotton was down significantly by 10 to 15%.

The fact that 51% of cotton plantings were biotech cotton in 2012 clearly demonstrates that Bt cotton in Burkina Faso continues to offer substantial benefits to farmers. The latest data on benefits from Bt cotton in 2011 includes an average yield increase of almost 20%, (19.7%) plus labor and insecticide savings (2 rather than 6 sprays), which resulted in a net gain of about US$95.35 per hectare compared with conventional cotton.

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Falck-Zepeda et al. (2008) studied potential payoffs and economic risks of adopting biotech cotton in 5 countries in West Africa namely; Benin, Burkina Faso, Mali, Senegal and Togo. The study concluded that Bt technology needs to be adopted, in order to ‘catch up’ with major cotton-producing countries in the rest of the world. Under the assumptions of the model, all of the studied countries would be worse off economically by not adopting Bt cotton. Referencing the cotton initiative in the WTO’s Doha Round of discussions, a paper from the World Bank (WPS3197, Anderson et al. 2006) concluded that cotton-growing developing countries in Africa and elsewhere should not wait until the Doha Round is completed before benefiting from increased income from cotton.

The higher yield of Bt cotton compared with conventional cotton results in a more competitive product for the international cotton market and higher profits for small resource-poor subsistence farmers, thus making a contribution to the alleviation of their poverty. The scientific work to evaluate performance and selection of the two approved varieties was done by local scientists under authority of Burkina Faso’s National Bio-Security Agency. The capability of local researchers to produce Bt cotton seed locally counters the long-held perception of dependency on foreign firms for seed. The State is co-owner of the genetically modified varieties with Monsanto. The price of the seed and the distribution of value added were determined by mutual agreement. Royalties have been negotiated in such a way that the technology fee accruing to Monsanto will be dependent on the farmer’s income. The general formula is that the value of increased yield plus savings in insecticide sprays will be considered as gross income which will be divided into three parts. Two-thirds will remain at the farm gate, thus, most of the gain goes to the farmers with the remaining one-third to be shared between Monsanto and the seed companies that provide the seeds for planting.

The cotton sector is well organized into village associations and cotton companies that have exclusive rights to buy seed cotton from producers and provide them with inputs, including seed. The main cotton producing regions are in the west which is covered by the Textile Fiber Company of Burkina Faso SOFITEX which controls 80% of production. FASO COTON situated in central Burkina Faso has 15% of production and the Cotton Society of Gourma (SOCOMA) takes care of production in six provinces in the east (SOCOMA, 2007) with about 5% of production.

Burkina Faso serves as an example within the Economic Community of West African States (ECOWAS) for its development capabilities in biotechnology with Bt cotton in a legal context. The Bt cotton program, initiated and expedited by the Government of Burkina Faso can serve as a model for many other developing countries growing cotton as well. It is also consistent with the recommendation of the 2008 G8 Hokkaido meeting which recommended the utilization of biotech crops acknowledging the significant and multiple benefits they offer. Burkina Faso, as the leader of the group of four cotton growing countries in West Africa (Burkina Faso, Benin, Chad and Mali) is now in a position to share its important knowledge and experience on Bt cotton with its neighboring countries, so that they, if they so wish, can expedite the commercialization of Bt cotton in their respective countries. This would ultimately expedite the commercialization process in those countries for the benefit of their cotton farmers. It is noteworthy that these countries are beginning to put regulatory mechanisms in place as a first step towards preparing themselves for the safe and responsible uptake of the technology. The National Assemblies of Mali and Togo for example, passed national biosafety laws in 2008 (James, 2008). In 2011, two other West African countries Ghana and Nigeria also passed their biosafety laws, an indication that the Burkina Faso experience is inspiring more and more countries into putting governance mechanisms for safe use of modern biotechnology.

Political Will and Support

President of Burkina Faso, Honorable Blaise Compaore's statement on GMOs during the National Peasants Day 2010 ***"In a continent that is hungry, the GM debate should be very different. The technology provides one of the best ways to substantially increase agricultural productivity and thus ensure food security to the people. In the cotton sector, for example, Burkina Faso has succeeded in increasing its production under current conditions, but it will be difficult to exceed one million tonnes. But with falling prices, we have no choice but to produce in quantity. And biotechnology may allow us to reach 2 to 3 million tons."***

Farmer Testimonials

Interview with Mahama Ilboudo, Cotton Farmer from Douaba Village – September 2011

Mr. Mahama Ilboudo is a small scale farmer from Douaba village in the southern central part of the country, about 80 km from Burkina Faso's capital city of Ouagadougou. The year 2011 was his 3rd consecutive year of growing transgenic cotton but has 13 years experience in cotton farming. He also grows millet, maize, groundnuts and eggplants in his 0.5 hectare of land. He has 2 wives and 10 children and therefore enough people to assist in the farm.

Asked to comment which of the two is more motivating to grow, Bt cotton and conventional cotton, given his long experience in cotton farming, he said, ***"Sincerely, there is no comparison between the two. I have grown Bt cotton since 3 years ago and I have realized that Bt cotton is far more beneficial than conventional cotton. Among other advantages, for Bt cotton, we have less spraying to do, which makes farming less strenuous compared to the work involved in growing conventional cotton. What is certain is that we save on time, which can be used to do other things. There is also a significance increase in terms of harvest."***

Unfortunately, he had problems with land ownership and could only plant 0.5 hectares of Bt cotton. He has tried to maximize on use of organic fertilizer to enrich the soil and give more nutrients to the cotton. His hope, like that of many Burkinabe farmers in his neighbourhood is that they will get enough yields from their small farms to feed the many mouths in the family. Challenges encountered include water scarcity, increased prices of farm inputs and equipment, and low prices for their cotton.

Interview with Tasséré Ilboudo, Bt cotton farmer, Bensboumbou village – September 2011

Fifty seven year old Mr. Tasséré Ilboudo is a resident of Bensboumbou village in Toécé section of Bazèga province, 80 km from the capital city of Ouagadougou. He is the chairman of the Bazèga Provincial Union of cotton farmers (UPPC). He has 4 wives and 16 children, and says everyone among those who are old enough works on the farm. He has been growing cotton for14 years. He also grows maize, millet and groundnuts. The year 2011 was his 3rd year of growing Bt cotton. He belongs to the Bensboumbou GPC (cotton farming group) composed of 100 farmers all of whom grew biotech cotton in 2011.

Asked why he and his group chose to grow Bt cotton, he laughs and says, ***"You know, every human being would like to improve his or her farm enterprise, in order to get enough funds to provide for his/her family. Our decision is clear; we have decided to grow GM cotton because we are satisfied in terms of its yield, and it gives us increased profitability. In addition to that, we do less spraying with Bt cotton. There were moments when our colleagues paid dearly for using pesticide. One day, one of our colleagues collapsed. We had to carry him to an emergency clinic. Fortunately he did not die. This means that by using too many pesticides, our health is threatened and even deteriorates."***

He has planted 4 hectares and says if the rains continued till 15 October 2011, the harvest would be very good. Generally he gets 1.1 tonnes per hectare on average. Therefore, he expects to harvest about 4.4 tonnes of Bt cotton. His advice to others: ***"It is the person inside the house who would know that its roof has holes or not and in our case, only a Bt cotton farmer would be able to testify on the benefits of Bt cotton. To my knowledge, nobody forced me or the farmers in my group to grow Bt cotton. We cannot do something which will not yield much interest, just for the purpose of satisfying somebody. Therefore, skeptical farmers should stop harming their business, especially now that we have an opportunity to get more money."*** Like other farmers in Burkina Faso, Tasséré expects better purchasing price for their cotton and reduced price for seed.

Interview with Mrs. Rakiéta Sawadogo, lady cotton farmer, Balavé village – October 2011

Mrs. Sawadogo Rakiéta comes from Mouhoun region in the Western part of the country, also known as the bread basket of Burkina Faso, which is 170 km from Bobo-Dioulasso, the second town of Burkina Faso and 535 km from the capital city of Ouagadougou. She belongs to the Wendsongdo cotton women farmer association. She is married with five children. They joined together as a group after realizing that cotton gives many benefits, which could help them deal with some of their problems. In her farmer group, twelve of them grow Bt cotton. They also grow ground nuts and sesame.

The year 2011 was their 2nd year to grow Bt cotton. Asked why they choose to grow Bt cotton, she said, ***"We chose to grow Bt cotton because we are women. The maintenance of conventional cotton is difficult. The labor involved in it is enormous for a woman. For example, it is really hard for a woman to carry the spraying machine and walk about a one hectare field, spraying. On the other hand, taking care of Bt cotton does not require much effort. It only requires two sprays instead of the six for conventional cotton."***

The association has 12 hectares of Bt cotton with some of the women having 0.5 hectares; others 1 hectare and larger ones having 2 hectares. Rakiéta has one hectare. She expects to harvest 1 tonne but with the lack of rains, she wouldn't make any prediction since at the flowering stage, the crop became weak. According to her, the most challenging thing was the delay in acquiring Bt cotton seeds. The other problem was the scarcity of rains. Due to lack of rains, some of the seeds rot and they were obliged to buy fresh Bt cotton seeds, which are expensive.

Asked why their group was not doing the 3rd year of growing Bt cotton like many others in the province she says, ***"Initially, people were saying that Bt cotton leaves can kill animals and Bt cotton causes bareness. This scared us but afterward, we realized that those were lies. So***

far, no animal has died of grazing on Bt cotton and some of our group members have given birth this year," she proudly concludes the interview.

MYANMAR

2012 is the seventh consecutive year of cultivation of the long staple insect resistant Bt cotton variety named "Silver Sixth" or "Ngwe chi 6". In 2012, "Ngwe chi 6", was planted on 300,000 hectares by 428,000 small farmers (average of 0.7 hectare of cotton). This is equivalent to an adoption rate of 84% of all the cotton grown in Myanmar, and up by 6% from 283,000 hectares in 2011-12. "Ngwe chi 6" is a bollworm resistant and high yielding variety broadly adapted to different environments in Myanmar. It was developed, produced and distributed by the Myanmar Industrial Crops Development Enterprise (MICDE). In 2010, the National Seed Committee (NSC) of the Ministry of Agriculture & Irrigation officially registered "Ngwe chi 6" for commercial cultivation, which had been used for the first time in 2006-07. "Ngwe chi 6" is very popular and has replaced all the long staple cotton hectarage within the first 7 years of its commercial release.

MYANMAR

Population: 50.5 million

GDP: US$26.5 billion

GDP per Capita: US$635

Agriculture as % GDP: 50.3%

Agricultural GDP: US$13.3 billion

% employed in agriculture: 70%

Arable Land (AL): 10.6 million hectares

Ratio of AL/Population*: 0.7

Major crops:

- Rice
- Pulses
- Beans
- Sesame
- Groundnuts
- Sugarcane
- Cotton

Commercialized Biotech Crop: Bt Cotton

Total area under biotech crops and (%) increase in 2012:
300,000 Hectares (+6%)

*Ratio: % global arable land / % global population

Myanmar with a population of 50 million is predominantly an agricultural based economy. Agriculture contributes more than half (50.3%) of the national Gross Domestic Product (GDP) of

US$26.5 billion or equivalent to US$635 per capita. Agriculture employs 70% of total population of the country which has two distinct agro-eco climates – the temperate North and tropical South. Approximately 4.5 million farm families cultivate various crops on an estimated arable land of 10.6 million hectares, with an average 2.35 hectare per farm family. It is estimated that around 3 million farms (two-thirds of all farms) cultivate less than an average 2 hectares. There are four principal crops – rice, pulses, cotton and sugarcane that ensure food self sufficiency and earn significant foreign exchange. Rice occupies 47% or 5.5 million hectares of the cultivated area and cotton occupies about 350,000 hectares (MCSE, 2001; UNEP GEF, 2006). Approximately half a million cotton farmers (an estimated 503,566) farming 368,000 hectares in 2007, cultivate an average 0.7 hectares of cotton per farm in the regions of Western Bago, Mandalay, Magwe and Sagaing (Tun, 2008). Traditionally, cotton farmers grew indigenously developed varieties of *Gossypium arboreum* (short staple) until the large scale commercial adoption of upland cotton varieties of *Gossypium hirsutum* (long staple) in the 1960s. In 2010, the National Seed Committee (NSC) of the Ministry of Agriculture and Irrigation registered the insect resistant Bt cotton variety “Ngwe chi 6” for commercial cultivation, that has become very popular and replaced all long staple cotton area within first 7 years of its commercial release. The Bt cotton variety “Ngwe chi 6” is a bollworm resistant and high yielding variety with wide adaption to local conditions. The “Ngwe chi 6” insect resistant variety is developed, produced and distributed locally by the “Myanmar Industrial Crops Development Enterprise (MICDE) of the Union of Myanmar (MICDE, 2012a). ISAAA Brief 43 (James, 2011) provides a detailed overview of agriculture, R&D and cotton crop in Myanmar.

Insect Resistant Bt Cotton in Myanmar

In 2010, for the first time, it was reported that Bt cotton was being widely grown in Myanmar (Gain Report BM0025 USDA/FAS 3 Nov 2010; Myanmar Times, 2010; MICDE, 2012a). The reports confirmed that a long staple variety named ‘Silver Sixth’ popularly known as “Ngwe chi 6” Bt cotton variety was developed in Myanmar in 2001. The National Seed Committee (NSC) of the Ministry of Agriculture & Irrigation registered the insect resistant Bt cotton variety “Ngwe chi 6” for commercial cultivation on 31 May 2010 (MICDE, 2012a). Following field trials at Mandalay’s research facilities the first release was in 2006-07. In the interim, cotton farmers have quickly switched to “Ngwe chi 6” with adoption increasing significantly from 8,300 hectares in 2007-08 to 140,000 ha in 2008-09, 270,000 hectares in 2009-10 and 2010-11, 283,000 hectares in 2011, and 300,000 hectares in 2012-13. Bt cotton was farmed by 428,000 farmers in 2012-13 compared to 375,000 in 2010-11 with increasing adoption of 75% in 2010-11 to 84% of 359,000 of total cotton hectarage which increased by 6% from 283,000 hectares in 2011-12. The insect resistant Bt cotton now occupies the entire long staple cotton hectarage in the country (Table 30).

In 2011-12, the only cotton area that was planted with conventional non-Bt cotton variety was the area with short staple cotton variety, for which Bt cotton varieties are not available; “Ngwe chi 6”

Table 30. Adoption of Bt Cotton in Myanmar, 2006 to 2012

Year	Adoption of Bt Cotton (ha)	Total Cotton (ha)	% Adoption
2006-07	<500	300,000	<1%
2007-08	8,300	368,000	2%
2008-09	140,000	360,000	39%
2009-10	270,000	360,000	75%
2010-11	270,000	360,000	75%
2011-12	283,000	358,000	79%
2012-13	300,000	359,000	84%

Source: Compiled by ISAAA, 2012.

is the only long staple Bt cotton variety released to date in Myanmar. According to the Ministry of Agriculture's Extension Department, approximately 75% of the cotton grown in Myanmar is long staple cotton whilst the balance of 25% is short staple. Over the years, there has been a noticeable decrease in area under short staple cotton to "Ngwe chi 6" – a long staple Bt cotton that has become very popular among cotton farmers and already replaced all long staple cotton area within first few years of its commercial release in 2006-07. The insect resistant long staple cotton variety "Ngwe chi 6" is a very high yielding variety as compared to Ngwe chi 1, Ngwe chi 2, Ngwe chi 3, Ngwe chi 4 and Ngwe chi 5 with average and potential yield of 1,112 to 1,976 kg per hectare. "Ngwe chi 6" produces long and strong fiber with staple length of 28.6-30.2 mm and ginning percentage of 37-39% which is preferred by domestic textile industry in the country. Table 31 shows the fiber quality parameters of "Ngwe chi 6" as compared to other commercial cotton varieties approved in Myanmar.

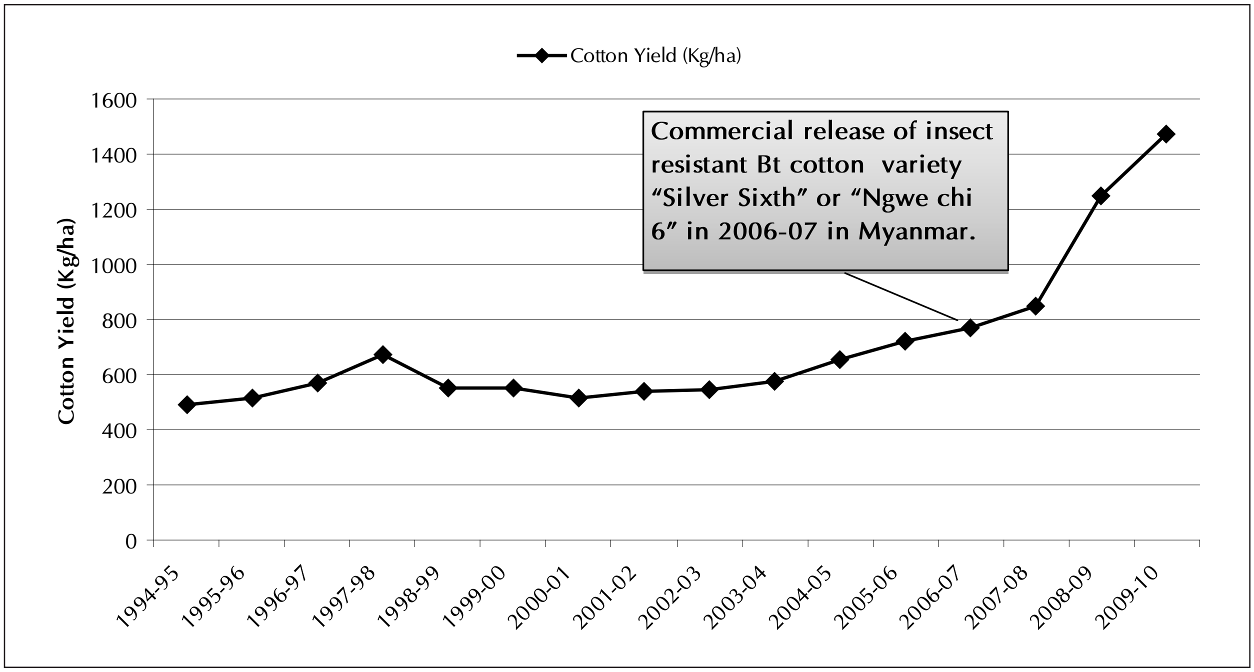
In 2009, Myanmar grew 360,000 hectares of cotton of which 270,000 hectares were long staple cotton producing 524,000 MT or 93 percent of total cotton production, whilst 68,000 hectares were short staple cotton producing only 38,000 MT or 7% of total cotton production (Figure 30). The yield of short staple cotton has grown at only 2.5% per year whilst the yield of long staple cotton has doubled since the introduction of "Ngwe chi 6" in 2006-07. The cotton yield has increased substantially from 770 kg per hectare in 2006-07 to 1,472 kg per hectare in 2009-10 as shown in Figure 30 (MICDE, 2012c). Yield losses from bollworms such as American bollworm and pink bollworms were significant, ranging from 30 to 70 percent (Nu, 2011). Therefore, the commercial release of Bt cotton variety "Ngwe chi 6" has imparted a significant control to insect pests resulting to a significant reduction in yield losses and a major contribution to steep yield increases in the last few years in Myanmar. Figure 31 shows the substantial increase in cotton production in the

Table 31. Fiber Quality Parameters of Ngwe chi 6 and Other Commercial Cotton Varieties Released in Myanmar

Name of Variety	Average Yield and Potential (Viss/Acre)*	Staple Length (mm)	Fineness (micronaire)	Strength (lb/mg)	Maturity Ratio	Ginning Percent (%)
Ngwe chi-1	400-500	27	4.3	8.0	0.9	35
Ngwe chi-2	400-650	29.4	3.9	8.5	0.9	36
Ngwe chi-3	450-700	30.2	3.4	8.7	0.9	34
Ngwe chi-4	400-600	29.5	3.7	8.4	0.9	35
Ngwe chi-5	400-550	28	4.5	8.3	0.94	37
Ngwe chi-6	450-800	28.6-30.2	3.8-4.2	7.8-8.5	0.97-1.0	37-39

*1 Viss = 1.65 kg
Source: MICDE, 2012b

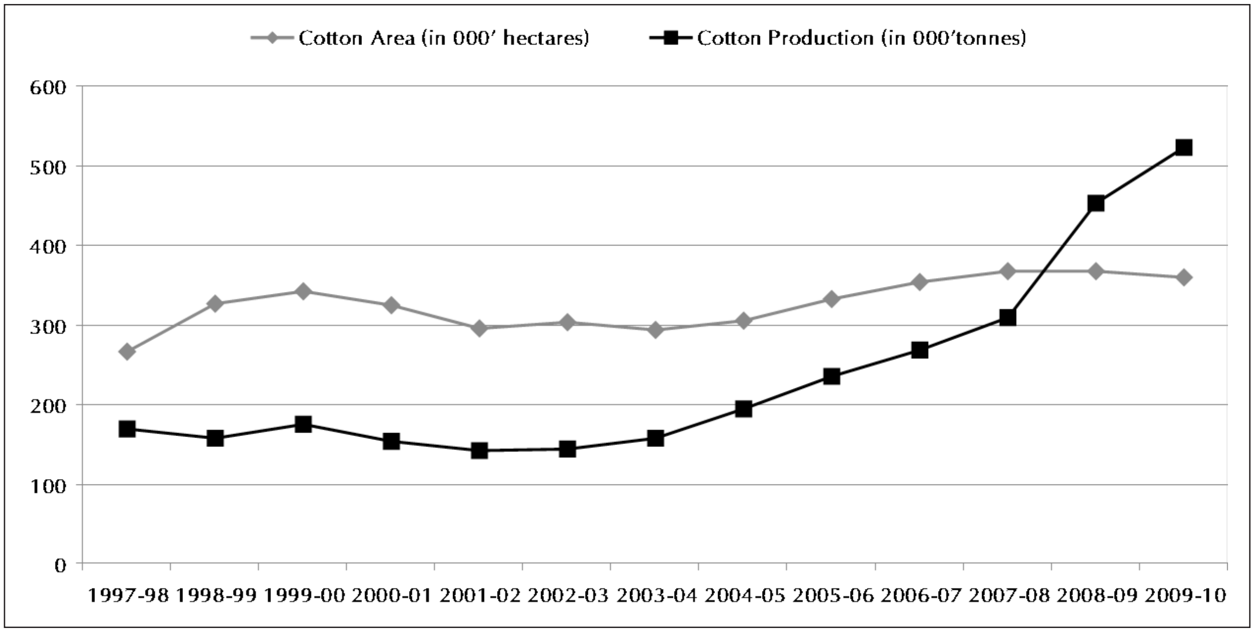
Figure 30. Cotton Yield in Myanmar, 1995 to 2010



Commercial release of insect resistant Bt cotton variety "Silver Sixth" or "Ngwe chi 6" in 2006-07 in Myanmar.

Source: MICDE, 2012c; Nu, 2011

Figure 31. Cotton Area and Production in Myanmar, 1997 to 2010



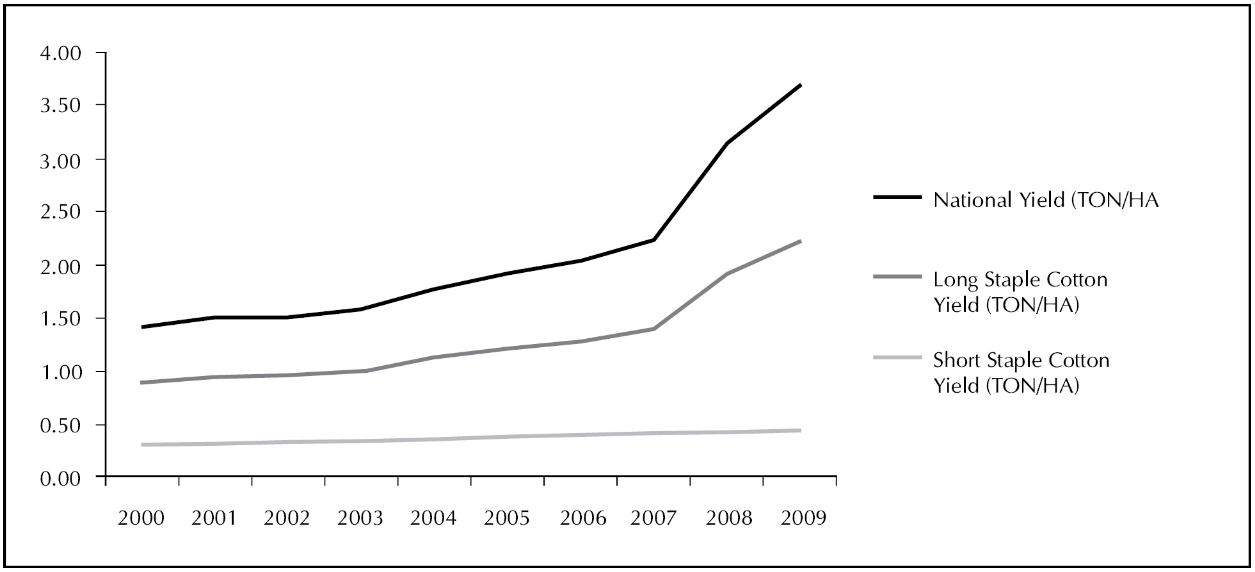
Source: Cotton and Sericulture Department, 2011; Nu, 2011

country between 2006-07 and 2009-10. Notably, the country, after a remarkable success with the deployment of insect resistant Bt cotton variety "Ngwe chi 6" is collaborating with national and international institutions to develop cotton hybrid seeds to exploit the potential of hybrid vigor for enhancing cotton yield and production in the country.

Benefits of Bt Cotton

It is estimated that more than 90% of long staple cotton producers in Myanmar have adopted Bt cotton. Compared to conventional long staple cotton, the best Bt cotton growers are estimated to have doubled or tripled yield using Ngwe chi 6 which requires one third less insecticides, resulting in a net significant increase in income (GAIN, USDA/FAS, 2010). The increase in income can be up to three times the income of competing crops such as beans, pulse and sesame, and can even be higher than the income from rice. Yield of long staple cotton has risen steeply from 2007 (coincides with introduction of Bt cotton Ngwe chi 6) to 2010 whilst the yield of the short staple cotton has remained stagnant (Figure 32).

Figure 32. Comparing Yield of Long Staple Bt Cotton, Short Staple Cotton and National Average, 2000 to 2009



Source: Adopted from GAIN, USDA FAS, 2010.

MEXICO

In 2012, Mexico planted 153,000 hectares of biotech cotton, equivalent to 97% of the 157,000 hectares of the national cotton hectarage and approximately 7,000 hectares of biotech RR®soybean for a country total of 160,000 hectares of biotech crops, compared to 175,500 hectares in 2011. The major reason for this modest decrease of 9% was drought, in the absence of which biotech cotton hectarage would have been approximately 200,000 hectares. The plan is to make Mexico self sufficient in cotton. Following productive discussions between the private, social and public sectors to develop a "best practices regulatory system" that would facilitate predictable access to biotech cotton for farmers in Mexico, approval has been granted to commercialize up to ~340,000 hectares of specific biotech cotton (BollgardII®/Flex and RR Flex) to be planted annually in specific northern states of Mexico. The most significant development in Mexico in recent years was the planting of the first biotech maize trials in the country in 2009, after an 11 year moratorium. The Mexican government approved 21 experimental field trials of GM maize. Mexico plants just over 7 million hectares of maize and imports about 10 million tons per annum at a foreign

exchange cost of US$2.75 billion. Mexico is estimated to have enhanced farm income from biotech cotton and soybean by US$180.2 million in the period 1996 to 2011 and the benefits for 2011 alone is US$44 million.

Mexico is the last of the six "founder biotech crop countries" having grown biotech Bt cotton in 1996, the first year of the global commercialization of biotech crops. In 2012, Mexico planted 153,000 hectares of biotech cotton, equivalent to 97% of the 157,000 hectares of the national cotton hectarage and approximately 7,000 hectares of biotech RR®soybean for a country total of 160,000 hectares of biotech crops, compared to 175,500 hectares in 2011. The major reason for this modest decrease of 9% was drought, in the absence of which, biotech cotton hectarage would have been approximately 200,000 hectares of biotech cotton. The data in Table 32 shows that 92% of all cotton was planted to the stacked gene HT/IR product favored by farmers, 5% as HT and the balance of 3% as conventional.

MEXICO

Population: 107.8 million

GDP: US$1,088 billion

GDP per Capita: US$10,230

Agriculture as % GDP: 4%

Agricultural GDP: US$43.5 billion

% employed in agriculture: 14%

Arable Land (AL): 25.6 million hectares

Ratio of AL/Population*: 1.0

Major crops:

- Maize
- Soybeans
- Cotton
- Wheat
- Rice
- Coffee

Commercialized Biotech Crops:

- Bt Cotton
- HT Soybean

Total area under biotech crops and (%) increase in 2011:
160,000 Hectares (-9%)

Farm income gain from biotech, 1996-2011: US$180.2 million

*Ratio: % global arable land / % global population

In 2012, a continuing modest hectarage of 7,000 hectares, of biotech soybean were planted in Mexico compared with 14,000 hectares in 2011 (Table 33). The reduced hectarage was due to a temporary restriction on planting of biotech soybeans in the Peninsula region of the country, where honey is produced.

Biotech Maize

Experimental field trials were conducted during 2011/2012 in the northern states of Mexico: Sonora, Sinaloa, Tamaulipas, Chihuahua and Coahuila which proved the effectiveness of maize biotech

Table 32. Biotech Cotton in Mexico, 2012

Trait	Total Hectares	% Biotech cotton
Bt/HT	145,000	92%
HT	8,000	5%
Conventional	4,000	3%
TOTAL	**157,000**	**100%**

Source: Compiled by Clive James, 2012.

Table 33. Biotech Soybeans in Mexico, 2012

Trait	Total Hectares	% Biotech soybean
Tamaulipas	60,000	946
San Luis Potosí	25,000	0
Veracruz	18,000	0
Subtotal Huasteca Plains	**103,000**	**946**
Chiapas	12,000	5,626
Campeche	11,000	0
Yucatán	1,500	0
Quintana Roo	1,000	0
Subtotal Southeast	**25,500**	**5,626**
TOTAL	**128,500**	**6,572**

Source: Compiled by Clive James, 2012.

traits. Additional approvals were also granted for field evaluations under the aegis of the Pilot phase project (pre-commercial) in Sinaloa and Tamaulipas during 2012. These trials were planted in January 2012 and harvested in July 2012. The trials generated important information regarding the use of adequate bio-safety measures that will allow coexistence of biotech and conventional maize. The trials also generated data on economic and environmental benefits for farmers. After completion of the Pilot phase, regulatory agencies will analyze the data and utilize it in consideration of granting commercial approvals for plantings of biotech maize in Mexico.

Mexico plants just over 7 million hectares of maize and imports about 10 million tons per annum at a foreign exchange cost of US$2.75 billion. The substantial gain in biotech cotton in Mexico is impressive. In addition, there were 7,000 hectares of herbicide tolerant soybean in Mexico with a

5% adoption rate, planted in two states in Mexico in 2012: Tamaulipas (946 hectares) and Chiapas (5,626 hectares, Table 33).

After being subject to an experimental regulatory system for the last 14 years, and in the framework of the Biosafety Law in 2011, the private sector through AgroBIO Mexico, the Agriculture and Environment Ministries and key agricultural sector representatives together evolved a cotton regulatory framework that incorporated the best practices for the advancement of experimental trials to a pre-commercial and commercial phase. This new Best Practice Regulatory Framework now provides an appropriate cost/time-effective system that is responsible, rigorous and more transparent, and has the resources to operate effectively. It has facilitated the increase of cotton production to a total of 153,000 in 2012 (97% biotech) and this is expected to generate a significant positive impact on the Mexican economy, including the creation of 7,000 additional direct jobs which will improve the income of more than 4,500 families.

Mexico is now positioned on a clear path to achieve in the midterm, cotton self-sufficiency and has the ability to become a key global exporter of this important crop. This success story is a good example of the benefits that can result from building alliances between Government authorities, farmer representatives and the private sector to support the ambitious expectations of Mexico to move forward to solidify its agricultural goals.

Mexico grows just over 8 million hectares of maize annually. The most significant development in Mexico in 2009/10 was the planting of the first biotech maize trials in the country. After an 11 year moratorium, the Mexican government approved 21 experimental field trials of GM maize. Following several years of debate, the Mexican Congress approved the GMO Biosafety Law on 15 February 2005 that permitted the introduction of biotech crops despite the debate regarding gene flow in maize. Under this law, authorization for the sale, planting and utilization of biotech crops and products is on a case-by-case basis, under the control of the Ministry of Agriculture and Ministry of Environment and policy coordination by the "Comision Intersecretarial de Bioseguridad de los Organismos Genéticamente Modificados" (CIBIOGEM), an inter-ministerial body. Increasing trade in biotech crops made this *ad-hoc* law necessary, and Mexican policy makers believe it was a major step forward in dealing with an issue that required urgent attention.

The Mexican government issued more permits for field trials in 2012 in the northern states of Mexico. Trials were conducted by independent scientists from recognized local Universities and Public Research Institutions. The evaluation was focused on three fundamental aspects: agronomic attributes of biotech maize versus its conventional counterpart; the biological effectiveness of insect resistant maize and the impact on non-targeted organisms; and the biological effectiveness of herbicide tolerance maize.

The field trials of biotech maize in Mexico have demonstrated that biotech maize is as safe as conventional maize, and effective; this is consistent with international experience with commercializing biotech maize in around 20 countries around the world for more than 15 years. Further trials already underway evaluate biotech maize pre-commercially (pilot phase); these trials generate valuable information regarding the use of adequate biosafety measures that will allow coexistence of biotech and conventional maize to be practiced on a realistic and pragmatic basis, as well as to provide accurate cost-benefit data regarding economic benefits for farmers. The granting of the first pilot permit approvals for biotech maize trials was an important step towards commercialization of biotech maize in the northern areas of the country and will partially offset expensive and growing imports of maize that has to be purchased with limited foreign exchange reserves.

Benefits from Biotech Crops in Mexico

Mexico is estimated to have enhanced farm income from biotech cotton and soybean by US$180.2 million in the period 1996 to 2011 and the benefits for 2011 alone is estimated at US$44 million (Brookes and Barfoot, 2013, Forthcoming).

SPAIN

> **Spain is the lead biotech crop country in Europe, with 90% of a record 129,071 Bt maize hectares planted in Europe in 2012. Spain has successfully grown Bt maize for fifteen years and grew a record 116,307 hectares of Bt maize hybrids in 2012, this compares with 97,326 hectares grown in Spain in 2011 equivalent to a substantial 20% increase from 2011. Total plantings of maize in Spain were 10% more in 2012 at 387,422 hectares compared with 351,141 hectares in 2011, leading to a record adoption of 30% in 2012, compared with 28% in 2011. Enhanced farm income from biotech Bt maize is estimated at US$139 million for the period 1998 to 2011 and for 2011 alone at US$28.5 million.**

Spain is the only country in the European Union to grow a substantial area of a biotech crop. In 2012, Spain grew 90% of all the 129,071 hectares of biotech maize in the EU. Note that the 2012 estimates by the Government of Spain include, Bt maize hybrids approved in other EU countries. Spain has successfully grown Bt maize for fifteen years since 1998 when it first planted approximately 22,000 hectares out of a national maize hectarage of 350,000 hectares. Since 1998, the area of Bt maize has grown consistently reaching a peak of over 50,000 in the last five years, qualifying Spain as one of the 16 biotech mega-countries globally growing 50,000 hectares or more of biotech crops. In 2012, the Bt maize area in Spain reached a record 116,307 hectares compared with 97,326 hectares in 2011 and the adoption rate in 2012 was a record 30% – almost a 20,000 hectare increase which is impressive. In 2012, total maize plantings at 387,422 hectares were 10% more than 2011 when the adoption rate was 28%. Thus, both absolute Bt maize hectares increased in 2012 by 18,981 hectares, as well as an increase in the adoption rate to 30% from 28%. The principal areas of Bt maize in Spain in 2012 were in the provinces of Aragon (41,669 hectares) where the adoption rate for Bt maize was 67% compared with 64% in 2011, followed by Cataluña (33,531 hectares) with the highest adoption rate of 90%, compared with 83% last year, with significantly more area of Bt maize in Extremadura (15,952 hectares), with an adoption rate of 26%; the balance of Bt maize was grown in eight other provinces in Spain in 2012 (Tables 33 and 34).

SPAIN

Population: 44.6 million

GDP: US$1,604 billion

GDP per Capita: US$35,220

Agriculture as % GDP: 3%

Agricultural GDP: US$48.12 billion

% employed in agriculture: 4%

Arable Land (AL): 12.6 million hectares

Ratio of AL/Population*: 1.1

Major crops:
- Grape
- Sugarbeet
- Maize
- Potato
- Wheat

Commercialized Biotech Crops: Bt maize

Total area under biotech crops and (%) increase in 2012:
116,307 Hectares (+20%)

Farm income gain from biotech, 1996-2011: US$139 million

*Ratio: % global arable land / % global population

Currently, more than 200 hybrids from about ten seed companies, all with the dominant event MON810 have been approved for commercial planting. Up until 2002, only the variety COMPA CB was grown with Bt-176 for insect resistance, and this variety was grown until the 2005 season. MON810 varieties for insect resistance were approved in 2003. There are about 200 registered hybrids of which 30 to 40 were estimated to have been planted in 2012. In November 2004, herbicide tolerant NK603 maize was approved for import, but the approval for planting in the European Union is still pending. When approved, biotech maize hybrids with NK603 are likely to be deployed throughout Spain.

Table 33. Hectares of Biotech Bt Maize in the Autonomous Communities of Spain, 1998 to 2012

Provinces	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Aragon	11,500	7,300	9,000	4,250	9,200	12,592	25,547	21,259	23,734	35,860	31,857	29,540	28,652	41,368	41,669
Cataluña	1,700	3,000	4,500	3,250	5,300	5,430	15,699	16,830	20,365	23,013	25,298	28,260	28,258	29,632	33,531
Extremadura	1,000	2,500	2,500	600	1,500	1,899	2,026	1,171	2,071	6,460	10,416	8,308	7,770	10,567	15,952
Andalucia	780	2,800	1,500	450	1,800	2,067	2,770	2,875	298	592	1,372	2,175	3,773	5,244	10,362
Castilla-La Mancha	4,500	6,800	5,650	870	4,150	7,682	8,197	7,957	4,176	3,659	4,739	3,128	3,187	5,817	7,883
Navarra	1,760	300	220	80	500	1,387	2,446	2,604	2,821	5,327	5,150	4,397	4,477	4,096	5,801
Valencia	190	300	150	100	20	72	73	293	0	0	14	0	23	107	522
Madrid	660	1,560	1,970	1,940	780	1,034	1,385	155	80	193	381	130	340	418	421
Islas Baleares	2	2	26	0	30	6	29	29	0	3	3	92	75	52	154
Castilla Y Leon	200	360	270	0	0	74	0	12	0	13	28	19	0	6	8
Murcia	0	0	0	0	0	0	12	0	0	24	0	0	0	0	4
La Rioja	25	30	30	0	0	0	35	41	122	4	11	8	5	21	0
Cantabria	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0
Asturias	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	**22,317**	**24,952**	**25,816**	**11,540**	**23,280**	**32,243**	**58,219**	**53,226**	**53,667**	**75,148**	**79,269**	**76,057**	**76,575**	**97,326**	**116,307**

Source: Ministry of Agriculture, Spain, 2012.

Table 34. Total Hectares of Maize Planted in Spain by Province, 2012 and Percentage Adoption of Bt Maize

Province	Total Hectares	Percent Bt Adoption
Castilla y Leon	104,986	<1
Aragon	62,382	67
Extremadura	60,400	26
Castilla-Mancha	39,727	20
Andalucia	38,002	27
Catalunia	37,190	90
Galicia	18,087	0
Navarra	17,095	33
Madrid	6,367	7
Canarias	645	0
La Rioja	625	0
Pais Vasco	437	0
C. Valenciana	415	13
Cantabria	325	0
Balearas	313	49
Pais de Asturias	300	0
R de Murcia	126	0
Total	**387,422**	**30%**

Source: Ministry of Environment Rural Development and Fisheries, Spain, 2012. Avances Suopefices y Producciones Agricolas, September 2012.

Spain is a feedstock deficit country and therefore, there is an incentive for Spanish farmers to increase productivity and be competitive, by employing innovative and cost effective technologies. The future growth of biotech maize in Spain will be dependent on the continued growth in the area planted to Bt maize, the approval of NK603, and particularly, a progressive and tolerant government policy especially in relation to coexistence.

Spain is the leader in biotech crops in the EU and conducts 42% of all the biotech field trials planted in the EU. In Spain, field trials of biotech crops are very carefully controlled and must be reviewed and recommended for approval by the National Biosafety Committee and are then subject to final approval by the Federal Government.

A survey of 200 farmers in Catalunia and Aragon in October and November 2011 showed that around 95% of farmers would plant biotech corn again in 2012. The survey by the Foundation for

Antama Markin entitled *Seeds of Bt Maize in Spain* showed that the preference of farmers were for biotech maize seeds with stacked traits of insect resistance and herbicide tolerance for planting in 2012, rather than the single Bt trait which is the only trait one approved for the EU (Crop Biotech Update, 20 January 2012).

The Spanish government through the Minister of Agriculture and Environment Miguel Arias Ceñete has further strengthened support to agricultural biotechnology, by claiming that transgenic maize is more environmental friendly than conventional maize crops. The Ministry is also preparing a new decree to establish the distances between genetically modified (GM) and organic crops in the field. A working draft on the coexistence of GM, conventional and organic crops is also being put in place (Crop Biotech Update, 29 July 2012).

Benefits from Biotech Crops in Spain

Spain is estimated to have enhanced farm income from biotech Bt maize by US$139 million in the period 1998 to 2011 and the benefits for 2011 alone is estimated at US$28.5 million (Brookes and Barfoot, 2013, Forthcoming).

The benefits to Spanish farmers from Bt maize has been reported by PG Economics and indicates that the average increase in yield was 6%, and the net impact on gross margin is US$112 per hectare. Data from the Institute of Agro-Food Research and Technology (IRTA, 2008), a public research institute in Spain indicates that for an area where the corn borer is prevalent, Bt-varieties have a yield advantage of 7.5% with an 83% reduction in levels of fumonisins. There is potential for increasing Bt maize hectarage in Spain, up to one-third of the total maize area, and the national gain is estimated at US$13 to US$18 million per year. The grain harvested from Bt maize in Spain is sold through the normal channels as animal feed or fed to animals on the farm.

Farmers' Views on Biotech Crops

Farmers from Spain, Romania and Portugal presented to the members of the European parliament (MPs) and representatives of the European Commission in Brussels a manifesto stating that ***"Biotechnology, a tool for agro-food cannot be ignored. The text in the rejection of positions and decisions against GMOs are not based in science. The safety of GM crops is guaranteed by the strictest and independent scientific assessment."***

The farmers stressed the inequality of the European Union in making decisions re. agricultural production and called for scientifically-based decisions so as not to discriminate against EU farmers who want to grow GM crops. Spanish farmers have also attested their experiences in planting GM crops saying that the cultivation of transgenic maize leads to higher yields in a more cost-effective way with higher quality grain and using less resources. The farmers noted that biotech crops which are available in other parts of the world, should also be enjoyed by farmers in the EU (Crop Biotech Update, 16 July 2010).

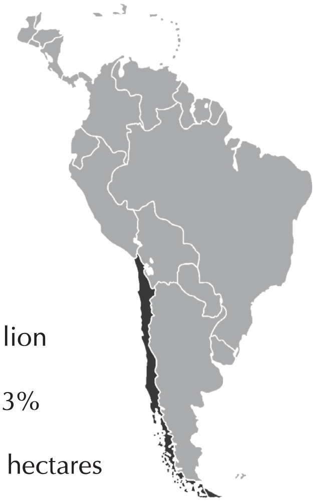
CHILE

In 2012, Chile grew an all time record of 62,300 hectares of biotech maize, canola and soybean, exclusively for seed exports – this is a ~50% increase over 2011, when 42,300 hectares were planted.

In 2012, Chile was projected to plant 45,000 hectares of biotech maize, 15,000 hectares of biotech canola and 2,300 hectares of biotech soybean for a total of 62,300 hectares for seed export; this is approximately 50% more than the 42,300 hectares planted in 2011-12.

Chile has a population of 16.8 million and a GDP of US$169 billion, 4% of which is generated from agriculture, and forestry is a strong sector in the country. Fruits are major exports worth US$2 billion per year and it has a thriving global export market in wines. A significant 13% of the population is involved in agriculture and the export market requires that the products are of top quality to compete in the global market.

CHILE



Population: 16.8 million

GDP: US$169 billion

GDP per Capita: US$10,080

Agriculture as % GDP: 4%

Agricultural GDP: US$6.8 billion

% employed in agriculture: 13%

Arable Land (AL): 1.5 million hectares

Ratio of AL/Population*: 0.4

Major crops:
- Fruits
- Wheat
- Maize
- Oats
- Rice

Commercialized Biotech Crops:
- Bt/HT Maize
- HT Canola
- HT Soybean

*Ratio: % global arable land / % global population

From a biotech crop standpoint, it is important to recognize that Chile is the sixth largest producer of export seed in the world in 2011, with a value of US$380 million (Table 1 in Appendix 2).

Chile has been producing biotech seed for export since commercialization began in 1996 and this activity is fully covered by the current law. Chile has clearly demonstrated over the last fourteen years that like the other 28 countries that commercialized biotech crops, it has all the necessary management know-how and skills to responsibly handle all the aspects related to the growing of biotech crops. The only difference between Chile and the other countries planting biotech crops is that the current law only allows commercialization of biotech crops for export. Commercialization and consumption of biotech crops produced in Chile are under consideration. This is a logical development given that Chile already imports significant quantities of biotech crops, such as biotech maize, for consumption from its neighboring country, Argentina, which is the third largest producer of biotech crops in the world. Chile has 120,000 hectares of maize which could benefit significantly from biotechnology and substitute for some of the imports of biotech maize from Argentina. Chile also has 80,000 hectares of potatoes which could benefit from biotechnology. The most recent REDBIO regional meeting on biotechnology recognized this opportunity for Chile to grow biotech maize for domestic consumption.

The area of biotech crops grown for seed export in Chile has shown a growth trend and plateauing over the last eight years, increasing from 10,725 hectares in 2002/03 to an all time high of 62,300 hectares in 2012 (Table 35). Multiplication of biotech seed for export is a significant business activity that was valued at approximately US$400 million in 2009, of which the value of biotech seed alone was at least US$200 million. Maize has always been the most important biotech seed crop grown in Chile and was at 45,000 hectares in 2012/13; the hectarage for biotech canola was 15,000 hectares and 2,300 for biotech soybean for seed export. The number of biotech seed crops multiplied in Chile is now more than 10 crop/trait combinations. The country has broad and diversified experience in successfully managing all aspects related to the growing of biotech crops for over 10 years.

Table 35. Hectares of Major Biotech Seed Crops Grown for Export in Chile, 2002/03 to 2012/13*

Crop	2002/ 03	2003/ 04	2004/ 05	2005/ 06	2006/ 07	2007/ 08	2008/ 09	2009/ 10	2010/ 11	2011/ 12	2012/ 13
Maize	10,400	8,450	7,614	12,120	17,981	25,000	30,000	28,000	9,378	25,000	45,000
Canola	110	140	746	628	444	2,500	4,200	1,200	3,500	15,000	15,000
Soybean	215	128	273	166	250	500	1,800	3,000	3,800	2,300	2,300
Total	**10,725**	**8,718**	**8,633**	**12,914**	**18,675**	**28,000**	**36,000**	**32,200**	**16,678**	**42,300**	**62,300**

Source: Government of Chile statistics, SAG, 2012. *industry estimates

Several organizations in Chile have been pursuing the development of biotech crop products for several years, including the following: The Catholic University of Santiago is developing citrus species that are resistant to drought and tolerant to nitrogen deficiency, virus resistant potatoes, and *Pinus radiata* species that are resistant to shoot moth and also tolerant to glyphosate. The National Institute for Agricultural Research (INIA) is developing grapes that are resistant to Botrytis, and in a joint program with the University of Santo Tomas they are developing stone fruits (nectarines and peaches) with improved quality and shelf life. Fundacion Chile provides technical and financial support for some of these projects.

Biotech activities in Chile are not restricted to crops but also include forestry products. Recently, some Chilean Research Institutes have joined forces to develop drought-tolerant Eucalyptus. Chile's Institute for Agricultural Research (INIA) and Chile's Forest Research Institute (INFOR) have announced a joint program to develop varieties of eucalypts, *Eucalyptus globulus*, with increased tolerance to drought. The project aims to provide farmers and forestry industry with plants and trees better adapted to the conditions of the arid interior regions of Chile. It is estimated that currently 1.8 million hectares of land are not realizing their production potential due to the low availability of water. More information can be obtained from INIA Chile (2007).

COLOMBIA

> **Colombia grew 28,172 hectares of biotech cotton in 2012, compared with 49,333 hectares in the previous year. In 2012, 23,500 hectares or 84% of the biotech cotton was the stacked product Bt/HT. Biotech maize was also grown on 75,046 hectares, compared to 59,239 hectares in 2011 in a "controlled program", but this hectarage is not included in the global data base. Colombia is estimated to have enhanced farm income from biotech cotton by US$44.3 million in the period 2002 to 2011 and the benefits for 2011 alone is estimated at US$20.6 million.**

In 2012, Colombia grew biotech cotton in two semesters. Of the 28,172 hectares grown in both semesters, 84% was stacked (IR/HT) and the balance of 16% was herbicide tolerance.

Biotech maize is not approved for commercialization in Colombia. However in 2012, Colombia, for the seventh year, planted biotech maize in two seasons in a "controlled planting program" in two regions, one on the Coast and Llanos region and the other in the interior of the country. Thus, in total for the first and second semesters, Colombia grew 75,046 hectares of biotech maize compared with 59,239 hectares in 2011. Of the 75,046 hectares, 54%, equivalent to about 40,667 hectares were the stacked traits Bt and herbicide tolerance (Bt/HT), 26,568 hectares were Bt maize (35%) and about 7,811 hectares were herbicide tolerant (HT, 11%). The biotech maize hectarage grown in Colombia is not included in the global biotech data for 2012 because it has not been approved for commercialization, and is only grown in a "controlled planting program."

Colombia has approximately 600,000 hectares of maize which could be an important new potential application for biotech maize. Colombia has been growing blue biotech carnation for export only since 2002, and in 2010 planted 4 hectares in greenhouses near Bogota which, although commercial, are not included in the global biotech hectarage.

Benefits from Biotech Crops in Colombia

A preliminary IFPRI study (Zambrano et al. 2011) on the benefits of biotech cotton for women indicates that it saved them time and money. This resulted from spending less time on weeding (an onerous back-breaking task) and on hiring men to spray insecticides, and generally freeing up their time for other important family activities. Importantly, a major unmet need for women growing biotech cotton, that needs to be remedied, is the lack of information from the various agencies involved, from the various public and private sector agencies involved in providing various services related to biotech cotton. The study confirmed that the gender focus on women is an important aspect and needs more detailed study in Colombia, where women, as is also the case in Africa, play a key role as practitioners in biotech cotton production.

Colombia is estimated to have enhanced farm income from biotech cotton by US$44.2 million in the period 2002 to 2011 and the benefits for 2011 alone is estimated at US$20.6 million (Brookes and Barfoot, 2013, Forthcoming).

Farmer Testimonies

Sergio Valencia, has farmed corn, soybeans, coffee, citrus, tomatoes, passion fruit, banana, and African palm in Llanos Orientales (Eastern Plains), Colombia for 20 years. He heard about the benefits of planting biotech maize in 2009 and has since then planted a 60 hectare field of biotech maize. Valencia believes that although the biotech maize seeds are slightly more expensive than conventional seeds, the extra expense translates into overall savings because planting biotech maize reduces the application of inputs. He explains that, ***"In a conventional maize crops, he would spend about 500 thousand pesos (approximately US$250) per hectare during a farming***

season. However, by planting biotech seeds, he has been able to reduce that amount to just 70 thousand pesos (approximately, US$35) per hectare. The use of biotech seeds has enabled him to save 86 percent in costs per hectare." He added that, ***"which means I get to enjoy more free time! I can focus in other activities in my farm or… just rest!"***

For all these benefits, he said, today ***"I do prefer biotechnology!"*** From now on he will continue to grow biotech crops in this region of Colombia, which has been catalogued as one of the most promising territories on agricultural development and production (Valencia, 2010).

HONDURAS

> **Honduras grew 27,000 hectares of biotech maize in 2012, 9,000 hectares more and equivalent to a 50% increase over the 18,000 hectares in 2011. In 2012, the 27,000 hectares of biotech maize comprised 25,000 hectares of Bt/HT maize and ~1,000 hectares each of HT maize and Bt maize.**

Honduras is a poor country in Central America with a GDP per capita of US$1,966 – one of the poorest in the region. Both large and small farmers cultivate maize which is the major staple in the country. The average yield is 1.6 tons per hectare which is one of the lowest in the region; this low yield is due to several factors, including lepidopteran pests which can cause significant losses, particularly on smallholdings.

Honduras was the first country to adopt biotech maize in Central America and introduced herbicide tolerant maize in 2002 with a pre-commercial introductory area of approximately 500 hectares. In the interim, the biotech maize area increased to 15,000 hectares in 2009, and a record 27,000 hectares in 2012. In 2012, the 27,000 hectares comprised 25,000 hectares of the stacked Bt/HT maize and 1,000 hectares each of HT maize and Bt maize. The national maize crop of Honduras is approximately 350,000 hectares.

Benefits from Biotech Maize in Honduras

Assuming a modest gain of US$75 per hectare from stacked biotech maize the national benefit from 15,000 hectares would be about US$1 million per year. Preliminary results from IFPRI studies, suggest that, not surprisingly, the larger farmers (over 2 hectares) have been the initial beneficiaries of biotech maize in Honduras and studies are underway to assess the impact of biotech maize in the country.

The experience of Honduras, as a small country with very limited resources in implementing a successful biosafety program can serve as a useful model and learning experience for other small countries particularly those in the Central American region. Zamorano University in Honduras has activities in biotech crops, including a knowledge sharing initiative which should contribute to a better understanding of biotech crops and facilitate more informed decisions about biotech crops, their attributes and potential benefits.

SUDAN

> **In 2012, Sudan became the fourth country in Africa, after South Africa, Burkina Faso and Egypt, to commercialize a biotech crop – biotech Bt cotton. A total of 20,000 hectares were planted in both rainfed areas and irrigated schemes. About 10,000 farmers were the initial beneficiaries who have an average of about 1-2.5 hectares of land. The total hectarage of Bt cotton was distributed in six of the major irrigated areas: Gezira, Rahad, New Halfa, Suki, Sennar and White Nile; and in the rain fed areas of Gadarif and Blue Nile State under large scale mechanized production system. The evaluation process, which started in 2009, using Chinese Bt cotton varieties, demonstrated efficient control of the major pest, cotton bollworm. The commercially grown Bt cotton variety named "Seeni 1" was released by the National Variety Release Committee in March 2012 and approved by the Biosafety Authority for commercial production in June 2012. Cotton is a major cash crop in Sudan but production has been declining over the last 5 years because bollworms are a major production constraint. The introduction of Bt cotton in Sudan is therefore a welcome change expected to boost cotton productivity and restore cotton as a main cash crop and a major contributor to the country's economy. Availability of seeds was a limiting factor in this first pilot season but the area is expected to expand rapidly in the coming season to reach substantial hectarage as many farmers are eager to grow Bt cotton.**

The Republic of Sudan is situated in north eastern Africa with international boundaries on the seven countries of Egypt, Eritrea, Ethiopia, South Sudan, the Central African Republic, Chad, Libya and South Sudan (Figure 33). Once the largest country in Africa, in July 2011, South Sudan was granted independence and Sudan became the third largest country in Africa after Algeria and the Democratic

Figure 33. Republic of Sudan, Formerly Northern Sudan Located in Northeastern Africa

Republic of Congo with a land mass of 1,882,000 square kilometers and a population of 33 million, at a population growth rate of 2.5%. The Blue and the White Niles run from the South to the North, and to the east the Sudan borders the Red Sea. The irrigated areas around the Nile are fertile and today, cotton is cultivated on about 150,000 hectares largely in the famous Gezira region. Almost half (46%) of the population in Sudan are poor and the goal is to reduce this to 23% by the MDG goal of 2015. Agriculture employs about 80% of the population and contributes a third of the GDP. Cotton and gum Arabic are the major agricultural exports while sorghum is the main food crop. Other important crops include wheat, peanuts and sesame, grown for domestic consumption.

Hamid Faki (2006) provides a succinct overview of cotton production in Sudan. Introduction of cotton in Sudan dates back to the first quarter of the nineteenth century, which was driven by interests and initiatives of the then Turkish-Egyptian rule. Success of its cultivation in a seasonally flooded delta in Eastern Sudan (Tokar) in 1862 triggered profound interest in the crop. This later provided good basis for a pilot investment in cotton production early in the twentieth century under pump irrigation in the northern part of the country by an American investor. A British company took over after three years of unsuccessful venture and managed to bring cotton production to a success. This drew attention to the vast flat arable "Gezira" lands between the Blue and White Niles as a potential area for cotton expansion to respond to the growing demand of the British textile industry.

Sudan has a long history of cultivating extra-long staple cottons, but the variety spectrum has broadened to include long, medium and short staple cottons. Of the 203,000 hectares of cotton grown in the 2003/2004 season, 118,000 hectares (58%) were under the long-staple variety "Barakat", 77,000 (38%) under the medium-staple "Acala", and 8,000 ha (4%) under the short staple varieties "Nuba and Acarain". Over the past decade, the share of cotton in Sudan's foreign export earnings has declined relative to other crops like sesame and livestock, even so, cotton still plays a major role in the economy. Cotton is an important source of income for a large number (200,000) of growers and their families. Cotton crop residues are also an important source of animal feed for a large number of livestock. The cotton industry also employs a considerable amount of hired seasonal labor during picking and ginning operations.

In 2012, Sudan became the fourth country in Africa after South Africa, Burkina Faso and Egypt to commercialize a biotech crop – biotech Bt cotton A total of 20,000 hectares were planted in both rainfed areas and irrigated schemes. About 10,000 farmers were the initial beneficiaries who have an average of about 1-2.5 hectares of land. The total hectarage of Bt cotton was distributed in six of the major irrigated areas: Gezira, Rahad, New Halfa, Suki, Sennar and White Nile; and, the rain fed areas in Gadarif and Blue Nile State under large scale mechanized production system. The evaluation process, which started in 2009, using Chinese Bt cotton varieties, demonstrated efficient control of the major pest, cotton bollworm. The commercially grown Bt cotton variety named "Seeni 1" was released by the National Variety Release Committee in March 2012 and approved by the Biosafety Authority for commercial production in June 2012. Cotton is a major cash crop in Sudan but production has been declining over the last 5 years because bollworms are a major production constraint. The introduction of Bt cotton in Sudan is therefore a welcome change expected to boost cotton productivity and restore cotton as a main cash crop and a major contributor to the country's economy. Availability of seeds was a limiting factor in this first pilot season but the area is expected to expand rapidly in the coming season to reach substantial hectarage as many farmers are eager to grow Bt cotton.

Most of Sudan's cotton is exported as lint. Major importers of Sudan's cotton are Egypt in Africa; Germany and Italy in Europe; and Thailand and Bangladesh in Asia. Compared with average export earnings of US$270 million during the 1970s, proceeds from cotton exports slumped to only US$42 million in 2001. In relative terms, local utilization of lint, mostly in textile industry, varies between 10% during the 1980s and 7% to 17% in recent years. However, in absolute terms, domestic lint consumption consistently declined from an average of 86 thousand bales during the 1980s to only 16 thousand bales in 2001 due to problems of the local textile industry. Earnest efforts are now being made to revive both cotton production and the domestic textile ndustry. The Bt cotton program is one such effort that responds to a real need and is poised to position Sudan back in the global map as a major player in the world cotton trade.

PORTUGAL

> **In 2012, Portugal planted an all time record of 9,278 hectares of Bt maize, compared with 7,724 hectares in 2011, a substantial 20% increase equivalent to 1,554 hectares. In 2012, the 9,278 hectares of Bt maize, were grown in 6 regions by Portuguese farmers. They first grew Bt maize in 1999, resumed successful planting in 2005, and since then, they have elected to continue to plant Bt maize for eight years because of the benefits that it offers.**

Portugal resumed the planting of Bt maize in 2005 after a five-year gap having planted an introductory area of approximately 1,000 hectares in 1999 for one year. In 2012, Portugal planted 9,278 hectares of Bt maize, compared with 7,724 hectares in 2011. The major six regions for planting Bt maize in Portugal are listed in Table 36 in descending order of percent adoption and contribution to the total Bt maize national hectarage of 9,278 hectares in 2012. The region of Alentejo had the largest hectarage of Bt maize at 5,796 hectares or 62% of the national hectarage. Alentejo was followed by the Lisbon and Tejo Valley regions with 2,322 hectares of Bt maize or 25% of the national hectarage.

Table 36. Major Regions Planting Bt Maize in Portugal, 2012

Region	Hectares	Percentage of National Bt Maize Hectares
Alentejo	5,796	62
Lisbon/de Tejo	2,322	25
Central	774	8
Acores	208	2
North	165	2
Algarve	13	<1
NATIONAL	**9,278**	**100**

Source: Ministry of Agriculture, Rural Development, and Fisheries, Lisbon, Portugal, www.dgadr.pt, 13 September, 2012.

The central region was the third region with 774 hectares of Bt maize or 8% of the national hectarage. Acores area was the fourth region with 208 hectares of Bt maize or 2% of the national hectarage of biotech maize. The Northern region was 5th with 165 hectares, and Algarve was the last region with 13 hectares equivalent to less than 1% of the national biotech maize hectarage. All the Bt maize in Portugal is MON 810, resistant to European corn borer. As a member country of the EU, Portugal's continued cultivation of Bt maize is an important development, acknowledging that the national maize area is modest.

The Government of Portugal passed a Decree, which requires a minimum distance of 200 meters between biotech and conventional maize and 300 meters between biotech maize and organic maize; buffer zones can substitute for these distances. Implementation of coexistence laws results in biotech maize being grown in the central and southern regions of Portugal where the farms are bigger, where coexistence distances can be accommodated and also, where producers are more responsive to the introduction of new and more cost effective technologies. The Ministry of Agriculture also passed legislation to establish biotech free areas where all the farmers in one town, or 3,000 hectare area, can elect not to grow biotech varieties. All biotech varieties approved in the EC catalogue can be grown in Portugal.

Benefits from Biotech Crop in Portugal

The area infested by the European corn borer (ECB) in Portugal are in the Alentejo and Ribatejo regions and the estimated infested area that would benefit significantly from Bt maize is estimated at approximately 15,000 hectares, which is equivalent to approximately 10% of the total maize area. The yield increase from Bt maize is of the order of 8 to 17% with an average of 12% equivalent to an increase of 1.2 MT per hectare. Assuming an average increase of US$150 per hectare the gain at the national level for Portugal for Bt maize would be in the order of increase of US$2.25 million per year.

Farmer Experience

Jose Maria Telles Rasquilla is a Portuguese farmer who has planted Bt maize since 1999. He says that, ***"Growing biotech maize offers environmental advantages and economic benefits such as better yields and less spraying, which means reduced costs, larger margins per hectare and good quality products. Developing new technologies and agricultural products can help the environment and have a positive impact on rural development."***

CZECH REPUBLIC

> **In 2012, the Czech Republic grew ~3,080 hectares of Bt maize in 2012, compared with 5,091 hectares in 2011. This decrease is mainly due to the onerous disincentives for farmers who are required to report intended biotech plantings to government authorities inconveniently early.**

The Czech Republic, more familiarly known as Czechia, approved the commercial production of a biotech crop for the first time in 2005 when it grew 150 hectares of Bt maize. In 2012, the Czech Republic grew ~3,080 hectares of Bt maize in 2012, compared with 5,091 hectares in 2011. The decrease was realized mainly because of the onerous disincentives for farmers who are required to report intended biotech plantings to government authorities inconveniently early. Czechia grew 150 hectares of the biotech potato Amflora in 2010 with none reported in 2012 because the product, which was well accepted by farmers, was not available for purchase by farmers because BASF discontinued sales of GM crops in the EU because of the hostile policy of the EU on biotech crops.

The latest information shows that Czechia grew up to 400,000 hectares of maize, of which the majority was for silage, and hence there is less incentive to grow maize for grain production where losses are higher than for silage. It is estimated that up to 30,000 to 50,000 hectares of maize are affected by the corn borer to a degree that would warrant the deployment of Bt maize planting, thus the potential for biotech maize expansion is significant. Coexistence rules apply with 70 meters between Bt maize and conventional maize (or alternatively 1 row of buffer is a substitute for every 2 meters of isolation) and 200 meters between Bt maize and organic maize (or alternatively 100 meters of isolation and 50 buffer rows).

Benefits from Biotech Crops in Czechia

The Phytosanitary Service of the Government estimated that up to 90,000 hectares were infested with European corn borer (ECB), and that up to 30,000 hectares were being sprayed with insecticide to control ECB. In trials with Bt maize, yield increases of 5 to 20% were being realized, which is equivalent to an increase of about US$100 per hectare. Based on 30,000 hectares of Bt deployed, the income gain at the national level could be of the order of US$3 million per year.

CUBA

> **In a landmark event, Cuba joined the group of countries planting biotech crops in 2012. For the first time, farmers in Cuba grew 3,000 hectares of hybrid Bt maize in a "regulated commercialization" initiative in which farmers seek permission to grow biotech maize commercially. The initiative is part of an ecological sustainable pesticide-free program featuring biotech maize hybrids and mycorrhizal additives. The Bt maize, with resistance to the major pest, fall armyworm, was developed by the Havana-based Institute for Genetic Engineering and Biotechnology (CIGB).**

Cuba, a country of 11 million people, imports around 60% of its food and feed, including large tonnages of maize, soy and wheat. Cuba has assigned high priority for increased agricultural output to contribute to "national security" following the unprecedented global food price crisis in 2008. Food and feed imports were valued at US$1.5 billion of foreign exchange in Cuba in 2009. During the food crisis of 2008, the situation was exacerbated due to three hurricanes that battered Cuba causing losses estimated at US$10 billion in damages and destroyed 30% of the country's crops, resulting in brief food shortages.

In a determined and carefully planned research effort to significantly increase productivity of maize, Cuba, has developed biotech Bt maize to control losses from the insect pest fall armyworm (*Spodoptera frugiperda*). Like many other tropical countries, armyworm is the most serious threat to maize production in Cuba, where it causes significant yield losses. The Bt maize is being developed and field-tested in a rigorously designed biosafety program, which meets the demanding standards of international protocols, by the country's internationally recognized Havana-based Institute for Genetic Engineering and Biotechnology (CIGB).

Extensive field tests in Cuba, featuring both Bt maize varieties and hybrids have demonstrated that the significant and multiple benefits associated with Bt maize are similar to those reported by other countries which have already commercialized Bt maize. These benefits include, reduction in insecticides for the control of fall armyworm, less exposure of farmers and the environment to pesticides, protection of the enhanced diversity of more prevalent beneficial insects, and sustainable increases in productivity of up to 30%, or more, depending on the severity of the armyworm infestation, which varies significantly with climatic and ecological conditions.

Multiple location field trials involving biotech maize were conducted in 2010 and continued in 2011. It is important to note that the field trials were part of an ecological sustainable pesticide-free program featuring biotech maize varieties and hybrids and mycorrhizal additives which generated excellent results with the biotech maize yielding up to 40% more than the conventional maize. The rigorously executed ecological program of regulated field trials is designed to address the issues of producers, consumers and society by comprehensively evaluating all aspects of the technology.

In the interim, an initiative for "regulated commercialization" has been underway in which farmers seek permission to grow biotech maize "commercially" – in 2011 up to an estimated 5,000 hectares of Bt maize varieties were grown under "regulated commercialization". The regulated commercialization program in Cuba is similar to the situation in several EU countries where farmers seek permission to grow Bt maize. In 2012, the regulated commercialization program featured hybrid Bt maize, rather than Bt maize varieties, and covered up to 3,000 hectares. The aim of increasing this Bt maize hybrid hectarage substantially overtime is to increase domestic maize production in Cuba with less reliance on imported maize. In a landmark development, Cuba, for the first time, is included in the group of countries that were cultivating biotech crops in 2012.

The Bt maize being developed by Cuba is similar to that grown on over 50 million hectares in 16 countries in 2012 alone. Thus, Cuba has the advantage of benefiting from the extensive and more than 15 years of commercial experience of a large number of countries in all continents of the world, including several EU countries, which have been successfully growing and benefiting from Bt maize for more than a decade, and which also import large tonnages of biotech crops. The potential benefits of commercializing Bt maize in Cuba are significant. The latest published import information indicated that Cuba imported significant tonnages of maize ranging from 599,917 tons in 2006 valued at approximately US$86 million to approximately 700,000 tons in 2007 to 2009 valued at up to US$200 million (Table 37). Some of these imports could be substituted by domestic production, if the yield losses due to armyworm alone, which are up to 30%, are controlled, thus making the country substantially more self-sufficient in maize production. This is a very important benefit to Cuba because the alternative is to keep relying on maize imports, which are likely to become more expensive as prices of staples trend upwards in the future. Work is also underway in Cuba to develop biotech soybean, potatoes and tomato, but unlike Bt maize, these biotech crops are at the R&D stage.

Table 37. Imports of Maize Grain into Cuba, 2006-2009

Maíze grain	2006	2007	2008	2009
Quantity MT*	599,917	708,389	716,984	682,526
Value $ million	86.6	146.9	207.5	147.4

Source: Annuario Estadistico de Cuba, 2009 * metric tonnes

EGYPT

In 2012, Egypt planted ~1,000 hectares of Bt yellow maize (MON 810) known in Egypt as Ajeeb YG®. This hectarage compares with 2,800 hectares in 2011 and was planted from early January 2012 before the temporary planting restriction of Ajeeb YG® was in place, pending further review by the Government. A socio-economic study conducted in 2011 indicated that the average increase in yield was 7% for Ajeeb YG®. Ajeeb compared with conventional hybrid maize, with a cost saving of 27% on insecticides and a gross margin of 18% in favor of Ajeeb YG®. Of the ~80 farmers participating in the survey, 88% indicated that they would elect to use Ajeeb YG® in the future because of the economic and environmental benefits associated with less need for applying insecticides and the higher yield and return. Egypt was the first Arab country to adopt biotech crops when it planted Bt maize in 2008 on 700 hectares, which climbed to 1,000 hectares in 2009, 2,000 hectares in 2010, and a high of 2,800 hectares in 2011.

Egypt with a population of 80 million, lies in the northeastern corner of Africa with a total land area of approximately 100 million hectares. It is bounded by the Mediterranean Sea to the North and the Red Sea to the East and Sudan to the South. The topography of Egypt is dominated by the river Nile, the longest river in the world, which provides the critical water supply to this arid country. Only 3% of the land, equivalent to approximately 2.5 million hectares is devoted to agriculture, making it one of the world's lowest levels of cultivable land per capita. However, agriculture is considered a principal sector in the economy contributing about 13% to GDP and providing close to 30% of employment. About 90% of the agricultural land is in the Nile Delta and the balance is within a narrow strip along the Nile between Aswan and Cairo. The rich cultivated land, irrigated by the Nile, is very fertile and allows double cropping. Nevertheless, the meager area of cultivable land as well as problems related to salinity and water, results in Egypt being dependent on imports for about half of its food supply. The principal crops are rice, wheat, sugarcane and maize. The government policy is to enhance agriculture as a major contributor to the national economy, by promoting privatization and decreasing government controls and subsidies. In 2011, the Minister for Agriculture and Land Reclamation Dr. Salah Farag, re-affirmed the use of biotech plants as one way of overcoming some of the serious problems facing the country. The major challenges for agricultural development in Egypt are the limited arable land base, erosion of land resources, loss of soil fertility and salinity and the high rate of population growth of 1.9%.

In 2012, Egypt planted ~1,000 hectares of Bt yellow maize (MON 810) known in Egypt as Ajeeb YG®. This hectarage compares with 2,800 hectares in 2011 and was planted from early January 2012 before the temporary planting restriction of Ajeeb YG® was in place, pending further review by the Government. Egypt was the first Arab country to adopt biotech crops when it planted Bt maize in 2008 on 700 hectares, which climbed to 1,000 hectares in 2009, 2,000 hectares in 2010, and a high of 2,800 hectares in 2011.

Egypt was the first country in the Arab world to commercialize biotech crops, by planting hybrid Bt yellow maize, Ajeeb YG®. The latest data indicate that Egypt grew approximately 660,000 hectares of maize in 2010, and annually imports 4.5 million tons of yellow maize valued at US$1.3 billion, based on US$275 per ton. Of the 660,000 hectares of maize in Egypt, 160,000 hectares (25%) are yellow maize and the balance of 500,000 hectares is white maize. The biotech maize hybrid is resistant to three maize insect pest borers (Massoud, 2005). Field trials were conducted from 2002 to 2007, which indicated that the yield of Bt yellow maize can be increased by up to a significant 30% over conventional yellow hybrid maize.

Egypt has a well established biotechnology institute, the Agricultural Genetic Engineering Research Institute (AGERI), which is the lead crop biotech institute in the Arab world, and the centre of excellence in biotechnology, molecular biology, and genetic engineering research focusing on product development. AGERI is within the Agricultural Research Centre (ARC) of the Egyptian Ministry of Agriculture and Land Reclamation. It is dedicated to the production of biotech crops and biotechnology-based products. AGERI's objective is to maximize production efficiencies with scarce water resources and arable land, reduce environmental degradation and minimize production risks for farmers. The institute is implementing a broad range of biotech crop activities, including the development of resistance to biotic stresses caused by viruses, insect, fungal pests and nematodes, and tolerance to the abiotic stresses of drought and salinity. Some basic research is also conducted on genome mapping, and protein and bio-molecular engineering. AGERI has several collaborative research programs with universities and institutions internationally. Several biotech crops are under development including wheat, barley and cotton tolerant to drought and salinity. Wheat is the most important crop in terms of crop value and increasing wheat production is considered a high priority in Egypt. Cultivated area of wheat crop is almost 1.23 million hectares with a total production of about 7.0 million tons/year. The total consumption of wheat is 14.0 million tons with a gap of 50% between production and consumption. A collaborative research team with AGERI has developed drought-tolerant transgenic wheat (with *hvaI* gene F13) which was cultivated in 2011. The event was evaluated under rainfed conditions at the North coast of Egypt with promising results. Some of the transgenic lines have 20% more grain yield than their non-transgenic parental genotype.

There is a suite of other projects incorporating resistance to various viruses in potato, squash and melons (zucchini yellow mosaic), tomato (tomato yellow leaf curl), and banana (bunchy top and cucumber mosaic). Similarly, there is also another set of projects incorporating resistance to insect pests, mainly featuring Bt genes, including projects on the *Gossypium barbadense* species of cotton (bollworm and other lepidopteran pests), potato (tuber moth), and maize (*Sesamia* stem borer), most of which are nearing commercialization.

Benefits from Bt Maize in Egypt

Developers of Ajeeb YG® have reported the following economic benefits in 2009. Increase in yield per hectare resulted in a gain of US$267, plus an insecticide saving equivalent to US$89 per hectare for a total gain of US$356 per hectare, minus the additional cost of seed per hectare at US$75 for a net benefit per hectare of US$281. Extrapolating from these data, the benefits from planting 1,000 hectares in 2012 is of the order of US$281,000. On a national basis the estimated annual opportunity cost to Egypt of not deploying Bt maize, based on a 33% and 66% adoption on the 160,000 hectares of yellow maize is US$15 million and US$30 million annually, respectively. Additionally, the use of Bt maize in Egypt would have an import substitution value, from increased self-sufficiency of maize plus savings of foreign exchange. A later socio-economic study conducted in 2011 indicated that the average increase in yield was 7% for Ajeeb YG®. Ajeeb compared with conventional, with a cost saving of 27% on insecticides and a gross margin of 18% in favor of Ajeeb YG®. Of the ~80 farmers participating in the survey 88% indicated that they would elect to use Ajeeb YG®. in the future because of the economic and environmental benefits associated with less need for applying insecticides and higher yield and economic return.

COSTA RICA

Costa Rica planted a small hectarage of biotech cotton and soybean for seed export for the first time in 2009, and continued to grow them in 2010, 2011 and 2012. Like Chile, Costa Rica plants commercial biotech crops exclusively for the seed export trade. In 2012, it planted approximately 91 hectares of biotech cotton, expected to increase to 300 hectares by year end 2012. Around 2,400 square meters of biotech soybean was already planted and expected to increase to 50 hectares by year end 2012.

Costa Rica is a Spanish speaking country with a population of approximately 4.5 million situated in Central America. Costa Rica is bounded by Nicaragua to the north, Panama to the east and south, the Pacific Ocean to the south and east, and the Caribbean to the East. The major cash crops for domestic consumption and exports are coffee, bananas and pineapples. About a quarter of Costa Rica is designated as national parks and the country was one of the first in the world to develop ecotourism. Whereas Costa Rica has only about 0.1% of the world's landmass, it contains 5% of the world's biodiversity. Expressed as a percentage of its land area, Costa Rica has the largest area of land devoted to national parks and protected areas than any other country in the world.

Costa Rica was included for the first time in 2009 in the global list of countries officially planting biotech crops, because like Chile, it plants commercial biotech crops exclusively for the export seed trade. The only difference between Chile and Costa Rica, and the other twenty seven countries planting biotech crops in 2010, is that the current laws in Costa Rica and Chile allow only commercialization of biotech crops designated for seed export. The biosafety law was promulgated in Costa Rica in 1998 (www.cr.biosafetyclearinghouse.net). The volume of biotech seed production in Costa Rica is small compared with Chile but has potential for growth. In 2011, approximately 3.0 hectares of biotech cotton were planted commercially, as well as about 0.1 hectare of biotech soybean for a total of 3.1 hectares. Cotton and soybean are planted in October and harvested in April/May of the following year.

Apart from the commercial production of biotech crops for seed export, Costa Rica is also continuing to field test biotech pineapples, featuring a nutritional quality trait and a disease resistant banana. These field tests were approved under the biosafety regulations of Costa Rica which conform to international standards.

ROMANIA

Romania grew its first 350 hectares of Bt maize in 2007 which increased to 7,146 hectares in 2008. Following the severe economic recession (particularly the restricted access to credit), the biotech maize area in 2009 declined to 3,243 hectares, to 822 hectares in 2010, 588 hectares in 2011 and 217 hectares in 2012. There were several factors involved in the lower hectarage in 2012 including onerous and bureaucratic reporting requirements for farmers regarding intended planting details and a limited supply of biotech Bt maize seed.

Up until 2006, Romania successfully grew over 100,000 hectares of RR®soybean, but on entry to the EU in January 2007, was forced to discontinue the use of an extremely cost-effective technology because RR®soybean is not approved for commercialized planting in the EU. This has been a great loss to both producers and consumers alike. It is noteworthy that because conventional soybeans yield substantially less (approximately up to 30%) than RR®soybean, the hectarage of soybeans has dropped precipitously in Romania from 177,000 hectares in 2006 to 48,000 hectares in 2009. Romania is estimated to have enhanced farm income from RR®soybean of US$45 million in the period 2001 to 2008 after which it had to discontinue planting when Romania became an EU member state.

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Even though Romania has ceased to grow RR®soybean, it is anticipated that Romania will resume growing RR®soybean if and when it is eventually approved for planting in the EU, thus it is appropriate to discuss the history of Romania and RR®soybean. Romania ranked equally with France as the third largest producers of soybean in Europe, after Italy and Serbia Montenegro, with approximately 150,000 hectares of soybean planted in 2007. Romania first grew herbicide tolerant soybean in 2001 when it planted 14,250 hectares of RR®soybean of its national soybean hectarage of approximately 100,000 hectares – a 15% adoption rate. In 2006, of its national soybean hectarage of 145,000 hectares, 115,000 hectares were planted with RR®soybean, equivalent to a 79% adoption rate. The very high adoption rate of 79% reflects the confidence of farmers in RR®soybean, which has delivered unprecedented benefits compared with RR®soybean in other countries, particularly in terms of yield gains. A study by PG Economics in 2003 estimated that the average yield gain was over 31%, equivalent to an increase in gross margins, ranging from 127 to 185%, or an average gain of US$239 per hectare that translates to an annual economic gain at the national level of between US$10 million and US$20 million. Given that RR®soybean technology is usually yield-neutral in other countries such as the USA and Argentina which have embraced the technology at high adoption rates, the yield increases in Romania are quite unprecedented. The high yield increases that ranged from 15 to 50% with an average of 31% reflect past low usage of herbicides and ineffective weed management, particularly of Johnson grass, which is very difficult to control.

Despite the above significant and unique advantages, a decision was taken by the Romanian Government, required by the European Union, to discontinue cultivation of biotech soybean as of January 2007 to qualify for membership in the EU, where RR®soybean has not been approved for planting. Many independent observers support the very strong views of Romanian farmers who are very much opposed to the decision to discontinue RR®soybean cultivation and believe that there were several compelling reasons for Romania to continue to grow RR®soybean after joining the EU, through a derogation. First, if farmers are denied the right to plant RR®soybean they will not be able to achieve as cost-effective weed-control program, even with more expensive alternates, resulting in significant financial losses for farmers growing conventional soybeans, and less affordable soybeans for consumers. Second, given that use of RR®soybean also results in better weed control in the crops following it in the rotation, elimination of RR®soybean leads to higher cost of weed control and more use of herbicides for all other crops following it in the rotation. This will result in negative implications for the environment because of more applications of alternative herbicides, which will also erode profitability. Thirdly, preclusion of RR®soybean legal plantings in Romania has reduced national production of soybean by up to one third which illogically can only be compensated with imports of exactly the same product – RR®soybean that has been banned, which will have to be purchased with scarce foreign exchange. Experience in other countries indicates that denying the legal use of RR®soybean to Romanian farmers will lead to illegal plantings of a significant magnitude with all its negative implications for all parties concerned.

As a 2007 accession country to the EU, Romania's positive experience over the last eight years with biotech soybeans has important policy implications vis-à-vis cultivation of biotech crops in all other EU accession countries like Bulgaria, and other neighboring countries in the Black Sea region. Romania's role model as a successful grower of biotech crops in Eastern Europe is clearly important, particularly since it was a 2007 accession country to the EU. Furthermore, Romania's success with biotech crops started with RR®soybean in 2001, followed by Bt maize in 2007, 2008 and 2009. Romania was the largest grower of maize in Europe – 2.5 million hectares in 2008, compared with 1.6 million hectares in France, 1.2 million hectares in Hungary, 1 million hectares in Italy and 0.4 million hectares in Germany. In this context, it is noteworthy that in 2007, in addition to Romania, seven other EU countries, Spain, France, Czech Republic, Slovakia, Portugal, Germany, and Poland successfully grew an increasing hectarage of Bt maize on approximately 110,000 hectares. Contrary to the findings of the European Food Safety Agency (EFSA) which declared that the event MON810 in Bt maize was safe to cultivate in Europe, France decided to discontinue Bt maize in 2008 and

Germany in 2009. In both cases, the evidence submitted by the two countries to support their rejection was not considered valid by EFSA – thus the decisions by both France and Germany to discontinue cultivation of Bt maize are in the view of EFSA, as an EU independent scientific organization, cannot be supported by scientific evidence.

Benefits from Biotech Soybean in Romania

There has been active debate on the use of biotech crops in Romania. The Romanian Minister of Agriculture strongly supports the resumption of growing biotech soybean, stating that the Ministry of Agriculture will support biotech soybean in the EU. The Romanian Senate has also supported biotech crops with an almost unanimous vote on an Emergency Ordinance to embrace biotech products as food, whereas the Ministry of the Environment has been ambivalent on the subject.

For RR®soybean, cultivated since 2001 and occupying 145,000 hectares in 2006, the yield benefits of 30% was unique – in all other countries, RR®soybean is a yield neutral technology. The high yield increases in Romania of 15 to 50% with an average of 31% reflect past low usage of herbicides and ineffective of weed management, particularly of Johnson grass, which is very difficult to control. A 2003 study by PG Economics estimated an average yield gain of 31% or more, equivalent to gross margin gains of 127 to 185% or an average gain of US$239 per hectare – equivalent to a national economic gain of US$10 and US$20 million, respectively.

Romania is estimated to have enhanced farm income from RR®soybean of ~US$45 million in the period 2001 to 2011 (Brookes and Barfoot, 2013 Forthcoming). Romania had to stop growing RR®soybean when it became an EU member country in January 2007, and since then, the hectarage of soybean in Romania has plummeted from 177,000 hectares in 2006 to only 46,000 hectares in 2008.

Farmer Experience

The experience of farmers, who are the practitioners of biotech crops are important because they are masters of risk aversion and have no compunction in rejecting any technology that does not deliver benefits. Romanian farmers embraced biotech soybean and, Romanian soybean farmer ***Lucian Buzdugan*** accurately predicted the fate of Romanian farmers – on entry to the EU, Romanian farmers would have to pay the high price of banning the technology.

"I can tell you that soybean farmers in Romania are very interested in biotech seeds. If one day our government says no more GMOs (genetically modified organisms), it's a disaster.

Before, yields were just 1,300 to 1,500 pounds per acre with conventional soybeans and are now averaging 2,500 to 3,000 pounds per acre with biotech varieties."

SLOVAKIA

> **In 2012, the hectarage of Bt maize in Slovakia was 189 compared with 761 hectares in 2011. The decrease is mainly due to the fact that maize in Slovakia is mostly for grain, (not silage) which has to be laboriously reported, which becomes an additional administrative chore and a disincentive for farmers seeking to plant Bt maize.**

Slovakia grew its first commercial biotech crop, Bt maize in 2006 when 30 hectares of Bt maize were grown for commercial production by several farmers. In 2007, the area increased 30-fold to 900 hectares and in 2008 it again increased by over 111% to 1,931 hectares. In 2012, the hectarage of Bt maize in Slovakia was 189 compared with 761 hectares in 2011. The decrease is mainly due to the fact that maize in Slovakia is mostly for grain, (not silage) which has to be reported, and which becomes an additional administrative chore and a disincentive for farmers seeking to plant Bt maize. As a result of several factors associated with the economic recession and decreased plantings of hybrid maize, the Bt maize hectarage in 2009 decreased to 875 hectares but increased again in 2010 to 1,248 hectares, equivalent to a significant year-over-year increase of 43%.

As an EU member state, Slovakia can grow maize with the MON810 event which has been approved by the EU for all of its 27 member countries. Slovakia is estimated to have grown 236,000 hectares of maize in 2008 comprising 157,000 for grain and 79,000 for silage.

Benefits from Biotech Crops in Slovakia

It is estimated that from a third to a half of the 240,000 hectares of maize in Slovakia is infested with European corn borer with the most severe infestations in the south of the country where most of the maize is grown. Yield gains conferred by Bt maize have been measured at 10 to 15%. The average gain per hectare from Bt maize is estimated at US$45 to US$100 per hectare. Thus, at the national level, the income gain for farmers, assuming 100,000 hectares of Bt maize, would be in the range of US$4.5 million to US$10 million annually in Slovakia.

POLAND

> **It is probable that Bt maize cultivation was practiced in Poland in 2012 but there was no registration of Bt maize hybrids in place and hence estimates of Bt maize hectares are not available for 2012. In 2011, Bt maize hectares were estimated at 3,000 hectares.**

Poland has a population of approximately 38.12 million and a GDP (nominal) of US$528 billion, 5% of which is generated from agriculture equivalent to US$26.4 billion per year. Agricultural products and food stuffs represent about 8% of total exports equivalent to US$6 billion per year. Agriculture provides employment for 15% of the population, the highest percentage in the EU of which Poland is a member.

It is probable that cultivation of Bt maize was practiced in Poland in 2012 but there was no registration of Bt hybrids in place and hence estimates of hectares are not available for 2012. In 2011, Bt maize hectares was estimated at 3,000 hectares. The latest information indicates that there was an estimated total of ~670,000 hectares of maize grown in Poland, of which 260,000 hectares, or 39%, was used for grain, and 61% or 410,000 hectares, used for silage. European corn borer (ECB) used to be limited to only a few regions in the South and South East, but it is now endemic in all regions of Poland and causes significant damage. Economic thresholds which merit the use of Bt maize as a control measure are at a 15% level of infestation for grain crops and 30% to 40% infestation for silage crops. Insecticide application to control ECB is infrequent due to lack of tradition, equipment, awareness of the significant damage the pest is causing and the small size of holdings and fields. *Trichogramma* is sometimes used as a biological control agent at a cost of US$90 to US$105 per hectare. Insecticide control, which is rarely used, cost about US$35 per hectare.

Some pre-commercial Bt maize was planted in Poland in 2006 on approximately 100 hectares. In 2007, Poland commercialized Bt maize for the first time when 327 hectares were planted. Based on the positive experience of farmers who planted the 327 hectares of Bt maize in 2007, the hectarage planted to Bt maize in 2008 increased more than 8-fold to 3,000 hectares and the hectarage remained the same from 2009 to 2011. In 2007, Poland had the distinction of becoming the eighth EU country to plant Bt maize. Bt yellow maize is being used in Poland for animal feed and/or for ethanol production.

The Polish President, Bronislaw Komorowski, signed a bill in 2012, effective 2016, which will allow the use of GM products in animal feed – this is to preclude Poland becoming non-competitive in meat production using more expensive non-GM animal feed. The Ministry of Agriculture indicated that GM crop cultivation (Bt maize) was probably practiced in Poland in 2012 but there was no registration of Bt maize hybrids in place and hence there are no estimates of Bt maize hectares in Poland for 2012. The Ministry indicated that the EU had cautioned Poland "to adjust the law to reduce the risk of penalties" (AllAboutFeed, 12 September 2012). Separately, in September 2012, in a very important ruling the highest court in Europe, The European Court of Justice (ECJ) ruled that EU member nations cannot ban the planting of biotech crops approved by the EU. This ruling is directed at countries like Poland, France, Germany, and Italy whose national Governments have banned the planting of EU approved biotech crops. It is ironic that Governments are breaking the rules that they have specifically agreed to as members of the EU.

Benefits from Bt Maize in Poland

In 2007, a report entitled "The benefits of adopting genetically modified maize in the European Union; first results from 1998 to 2006 plantings," Graham Brookes (Personal Communication, 2008) reported that gross margins from Bt maize, over conventional, based on trials conducted in 2006 were on average approximately 25% higher, and associated with an increase of 2.15 tons/ha. A significant advantage of Bt maize, not captured in the benefits associated with yield increase is the substantial decrease in mycotoxin level with multi-fold decreases in the levels of all the various toxins. For example, Fumonisin B1 decreased from a range of 121 to 409 ppm in conventional maize to 0 to 25 ppm in Bt maize. Similarly, Fumonisin B2 decreased from a range of 44 to 103 ppm in conventional maize to a range of 0 to 8 ppm in Bt maize.

THE EUROPEAN UNION (EU 27)

Five EU countries continued to plant a record 129,071 hectares of biotech Bt maize in the EU in 2012, equivalent to a 13% increase over 2011 – this compares with 114,490 hectares in six countries in 2011. The five countries, in decreasing order of hectarage were Spain, Portugal, Czechia, Romania and Slovakia. No estimate was available for Poland although Bt maize was probably being planted, consistent with EU approval of Bt maize MON810. Farmers in two countries, Sweden and Germany, who planted Amflora potato in 2011 were denied the privilege to plant it in 2012 because Amflora was not available from its developer, BASF, for commercial planting in the EU. Spain was by far the largest EU Bt maize grower with 90% or a record 116,307 hectares of the total 129,071 Bt maize in the EU with a record adoption

rate of 30% in 2012, compared with 28% in 2011. Bt maize hectarage increased significantly by ~20,000 hectares in the two largest Bt maize countries Spain and Portugal and decreased marginally by ~3,000 hectares in Czechia, Romania and Slovakia. The marginal decreases in Bt maize in Czechia, Romania and Slovakia were associated with several factors, including disincentives for some farmers due to bureaucratic and onerous reporting of intended plantings of Bt maize, and a limited seed supply.

In July 2012, the EU Commission's Chief Scientific Advisor, Dr. Anne Glover, stated that genetically modified organisms (GMOs) are no riskier than their conventionally farmed equivalents. She further clarified that *"there is no substantiated case of any adverse impact on human health, animal health or environmental health, so that's pretty robust evidence, and I would be confident in saying that there is no more risk in eating GMO food than eating conventionally farmed food,"* – as a result she concluded that *"the precautionary principle no longer applies".* Dr. Glover emphasized that she was not promoting GMOs, and added that *"eating food is risky" – most of us forget that most plants are toxic, and it's only because we cook them, or the quantity that we eat them in, that makes them suitable."* She called for countries impeding GMO use *"to be put to proof".*

In 2011 a Kenyan national criticized the EU's opposition to GM crops stating that this was *"robbing"* Africa of the *"chance to feed itself and could threaten food security."* Dr. Felix M'mboyi of the African Biotechnology Stakeholders Forum criticized the European Union of *"hypocrisy and arrogance"* and called for *"development bodies within Europe to let African farmers make full use of GM crops to boost yields and feed a world population expected to reach 7 billion by the end of the year."*

In September 2012, in a very important ruling by the highest court in Europe, The European Court of Justice (ECJ), ruled that EU member nations cannot ban the planting of biotech crops approved by the EU. This ruling is directed at countries like France, Germany, Italy and Poland which have ilegally banned the planting of EU approved biotech crops.

EFSA reviewed a publication by Seralini *et al*, 2012 with the first review published in 3 October, 2012 and the final concluding report published on 28 November 2012. EFSA determined that the conclusion drawn by the authors in the publication could not be supported by the data presented. The self explanatory EFSA abstract of its final concluding review (EFSA, 2012) is reproduced here in its entirety.

ABSTRACT

On 19 September 2012, Séralini *et al.* published online in the scientific journal Food and Chemical Toxicology a publication describing a 2-year feeding study in rats investigating the health effects of genetically modified maize NK603 with and without Roundup WeatherMAX® and Roundup® GT Plus alone (both are glyphosate-containing plant protection products). As requested by the European Commission, EFSA reviewed this publication taking into consideration assessments conducted by Member States and any clarification given by the authors. The assessments of Member States and EFSA revealed an overall agreement. The study as reported by Séralini *et al.* was found to be inadequately designed, analysed and reported. The authors of Séralini *et al.* provided a limited amount of relevant additional information in their answer to critics published in the journal Food and Chemical Toxicology. Taking into consideration Member States' assessments and the authors' answer to critics, EFSA reaches similar conclusions as in its first Statement (EFSA 2012). The study as described by Séralini *et al.* does not allow giving weight to their results and conclusions as published. Conclusions cannot be drawn on the difference in tumour incidence between treatment groups on the basis of the design, the analysis and the results as reported. Taking into consideration Member States' assessments and the authors' answer to critics, EFSA finds that the study as reported by Séralini *et al.* is of insufficient scientific quality for safety assessments. EFSA concludes that the currently available evidence does not impact on the ongoing re-evaluation of glyphosate and does not call for the reopening of the safety evaluations of maize NK603 and its related stacks. EFSA's evaluation of the Séralini *et al.* article is in keeping with its role to review relevant scientific literature for risk assessment on an ongoing basis to ensure that the advice it provides is up-to-date.

Key words: Maize NK603, Roundup, glyphosate, experimental design, rat/rodent feeding study, toxicity, carcinogenicity

The review was conducted on request from European Commission Question No. EFSA-Q-2012-00841, approved on 3 October 2012. Correspondence: sas@efsa.europa.eu

The European Union comprises 27 states, a population of almost 500 million (7% of global) with a GDP in 2010 of US$17 trillion, equivalent to over 22% of global GDP. Less than 6% of the EU's workforce is employed in agriculture and the principal major crops occupy just over 90 million hectares (versus 1.5 billion hectares globally) of which maize is 13 million hectares, about 10% of global hectarage. There are approximately 15 million farms in the EU; Romania has the largest number of farms (almost a third of the EU total, followed by Poland, Italy and Spain). Table 38 summarizes the planting of Bt maize in the countries of the European Union from 2006 to 2012.

Five EU countries continued to plant a record 129,071 hectares of biotech Bt maize in the EU in 2012, equivalent to a 13% increase over 2011 – this compares with 114,490 hectares in six countries

Table 38. Hectares of Bt Maize Planted in 2006 to 2012 in EU Countries*

	Country	2006	2007	2008	2009	2010	2011	2012	Change 2011/12
1	Spain	53,667	75,148	79,269	76,057	76,575	97,326	116,307	18,981
2	Portugal	1,250	4,263	4,851	5,094	4,868	7,724	9,278	1,554
3	Czechia	1,290	5,000	8,380	6,480	4,680	5,091	3,080	-2011
4	Romania*	– –	350	7,146	3,244	822	588	217	-371
5	Slovakia	30	900	1,900	875	1,248	761	189	-572
6	Germany*	950	2,685	3,173	– –	– –	– –	– –	– –
7	Poland	100	327	3,000	3,000	3,000	3,000	N/A	-3,000
	Total	**57,287**	**88,673**	**107,719**	**94,750**	**91,193**	**114,490**	**129,071**	**+ 14,581**

* Germany discontinued planting Bt maize at the end of 2008 and grew 2 hectares of Amflora potato in 2011. Sweden grew 15 hectares of Amflora in 2011. Farmers in Germany and Sweden who had a positive experience with growing Amflora in 2011 were denied the privilege in 2012 because BASF discontinued the development and marketing of biotech crops for the EU because of the EU's' hostile policy on biotech crops and shifted its research activities to the US. Romania grew 145,000 hectares of RR®soybean in 2006 but had to cease growing it after becoming an EU member in January 2007.

Source: Compiled by Clive James, 2012.

in 2011. The five countries, in decreasing order of hectarage, were Spain, Portugal, Czechia, Romania and Slovakia. No estimate was available for Poland although Bt maize was probably being planted, consistent with EU approval of Bt maize MON810. Farmers in two countries, Sweden and Germany, who planted Amflora potato in 2011 were denied the privilege to plant it in 2012 because Amflora was not available from its developer, BASF for commercial planting in the EU. Spain was by far the largest EU Bt maize grower with 90% or a record 116,307 hectares of the total 129,071 Bt maize in the EU with a record adoption rate of 30% in 2012, compared with 28% in 2011. Bt maize hectarage increased significantly by ~20,000 hectares in the two largest Bt maize countries Spain and Portugal and decreased marginally by ~3,000 hectares in Czechia, Romania and Slovakia. The marginal decreases in Bt maize in Czechia, Romania and Slovakia were associated with several factors, including disincentives for some farmers due to bureaucratic and onerous reporting of intended plantings of Bt maize, and a limited seed supply.

All five EU countries which grew Bt maize commercially in 2012 provided benefits to farmers, to the environment and a more affordable feed source for animals, which in turn benefited consumers who eat meat.

Slow Approval of GM Crops in the EU

In October 2011, European biotech industry warned the EU Commission that slow approval of biotech crop imports, critical as feed-stocks, pose a risk for the EU that could disrupt supply of animal feed-stocks. Consumers in the EU are highly dependent on a massive import of 30 million tons of biotech animal feed annually, equivalent to a significant 60 kg per person. The report highlighted the anomaly that as feed exporting countries in the world such as Brazil (8 products approved in 2010 alone, 6 in 2011, and 3 in 2012) increases the pace of approval; the EU is slowing it down. On average, the EU's approval process is 15 to 20 months longer than the corresponding process in the three major feed exporters to the EU, the US, Brazil and Canada. The number of biotech crops pending approval in the EU has increased from 50 in 2007 to 72 in 2011– 51 for import and 21 for cultivation. It is projected that the number of products that will be pending approval in 2015 will increase to 90. Only two biotech crops were approved for cultivation in the EU (Bt maize and Amflora potato) in 2011, compared to 90 in the US and 28 in Brazil. In addition to denying EU farmers the right to grow biotech crops, the lack of approvals contribute to price volatility and import disruptions when the presence of unapproved events is detected. The EU Commission drafted a proposal in 2010 to empower EU member countries to decide whether to cultivate biotech crops or not, which could accelerate the approval process, however the proposal was blocked (AllAboutFeed.net, 13 October 2011).

On September 3, 2012, the European Commission has years of delays in approval decisions on GM products which when combined has a sum of 37 years, according to the position paper released by the European Association for Bioindustries' (EuropaBio). The EU legislation requires the Commission to follow certain timelines for decision making, but the timelines for approval of GM products regularly exceed the required timelines. This delay results to a continuously increasing backlogs of GM product approvals, at the same time, a number of developing countries are already adopting GM products, and exporting their commodities to the EU (Crop Biotech Update, 26 September 2012).

A University of Reading study in 2011 (Park et al. 2011) on the Impacts of the EU regulatory constraints of transgenic crops on farm income, revealed that ***"if the areas of transgenic maize, cotton, soya, oilseed rape and sugarbeet were to be grown where there is agronomic need or benefit, then farmer margins would increase by between €443 and €929 million per year." It was also noted that "this margin of revenue foregone is likely to increase with the current level of approval and growth remains low, as new transgenic events come to market and are rapidly taken up by farmers in other parts of the world."***

A study by a group from the University of Leuven, Belgium (Demont et al. 2007) concluded that the potential annual value of biotech crops for an average EU country can be up to US$60 million per year and that biotech sugarbeet alone could generate annual gains in the order of US$1 billion per year for the EU. A more recent study by EMBO (Fagerström, et al. 2012) reported that EU farmers denied the privilege of using biotech sugarbeet, potato and canola, are costing them and the EU annually approximately €2 billion (US$2.5 billion plus a saving of approximately 645,000 hectares which corresponds to a capital value loss in the range of €80 to €120 billion over several years. The report condemns the EU on three counts: first for allowing legislation to be "completely out of proportion compared with other science based endeavours, second "risk research in Europe is not helping to develop sustainable agriculture for the future", and third, "that it is time to acknowledge the distinct imbalance with respect to the costs and benefits of GM crops… due to the submissive attitude of politicians and policy makers towards organizations who insist that GM crops are risky."

Opinions on GM Crop Policy in EU

In 2011 a Kenyan national criticized the EU's opposition to GM crops stating that this was "robbing" Africa of the ***"chance to feed itself and could threaten food security."*** Dr. Felix M'mboyi of the African Biotechnology Stakeholders Forum criticized the European Union of ***"hypocrisy and arrogance"*** and called for ***"development bodies within Europe to let African farmers make full use of GM crops to boost yields and feed a world population expected to reach 7 billion by the end of the year."***

Mr. Gilbert Arap Bor is a Kenyan framer who grows maize and vegetables and raises dairy cows on his 25-acre farm near Kapseret. He recently shared his views on biotech crops and the EU regulatory policy. ***"Thankfully, Kenya is beginning to take positive steps. Last year, our government approved the commercial planting of genetically modified crops, becoming the fourth African country to do so after Burkina Faso, Egypt and South Africa. This will give our farmers access to one of the world's most important hunger-fighting tools. We can also draw upon tremendous resources in human capital, from the scientific expertise at the Kenya Agricultural Research Institute to the business know-how of the Kenya Seed Company… the billions in aid that Europe sends to Africa every year do nothing to encourage the use of agricultural technology, and often discourage or prevent it. Africa's farmers and their would-be customers are being held hostage by scientific illiterates whose well-paid jobs involve raising money by frightening people about biotechnology"*** (Bor, 2011).

Food Safety of GM Maize MON810

Contrary to the findings of France and Germany, EFSA has clearly stated, that ***"No specific scientific evidence, in terms of risk to human and animal health and the environment, was provided***

that would justify the invocation of a safeguard clause" (EFSA, 2008). A report in September 2008 by the EU's Joint Research Council (EU-JRC, 2008) concluded that, ***"No demonstration of any health effects of GM food products submitted to the regulatory process that has been reported so far."*** This finding of the JRC endorsing the safety of biotech crops is consistent with many independent studies conducted over the last several years including the Nuffield Bioethics Council, the Royal Society and the EU's EFSA. The latest report (EU-JRC, 2008) suggested that, ***"Europe must 'move forward' and clear biotech crops amid increasing food prices."***

On 8 Sept 2011, Europe's highest court, the European Court of Justice ruled against future unilateral decisions by EU countries to ban biotech crops, particularly France, without informing the EU commission and without evidence "of a situation which is likely to constitute a clear and serious risk to human health, animal health or the environment." The decision was precipitated by a 2008 ban by France on the planting of MON 810 Bt maize. Six other countries, Austria, Bulgaria, Germany, Greece, Hungary and Luxembourg also banned the same product. Whereas the ruling, is not legally binding, it was referred to France's highest administrative court for consideration and if the Council of State, which ratified the ruling, and logically the government would have to abandon its "safeguard clause" against biotech crops. The ruling was welcomed by French farmers as a step towards pro-choice in Europe and that they would no longer be denied the opportunity to benefit from Bt maize which is planted in several countries in the EU led by Spain and Portugal. However France continued to maintain the ban. To-date the EU Commission has allowed individual EU states to impose the ban if compatible with World Trade Organization rules, and if the EU is notified first. In a separate ruling the European Court of Justice ruled that honey containing even tiny traces of pollen from biotech maize could not be sold in the EU without prior authorization (Expatica.com, 8 September 2011).

A crucial decision was made in 2011 by the highest court of France, the Conseil d'Etat – it declared that the 2008 decision by the European Court of Justice to ban the cultivation of genetically modified crops in France was illegal (Seed Today, 28 November 2011). The French government was not able to present scientific evidence of any risk to health or the environment from these crops, thus, both the EU and the French high court overturned the national ban, however the Government continued to maintain its ban.

In September 2012, the highest court in Europe, The European Court of Justice (ECJ) ruled that EU member nations cannot ban the planting of biotech crops approved by the EU (EuropaBio, 7 September 2012; ICSTD, 14 September 2012). This ruling is directed at countries like France, Germany, Italy and Poland which have banned the planting of EU approved biotech crops (Bridges Trade BioRes Review, October 2009). The Bt maize MON810 and the biotech Amflora potato are the only two biotech crops approved by the European Food Safety Authority (EFSA) and 16 countries grew MON 810 Bt maize in 2012. The ECJ ruling states that "the cultivation of genetically modified organisms such as the MON 810 maize varieties cannot be made subject to a national authorization procedure when the use and marketing of those varieties are authorised pursuant to Article 20 of Regulation (EC) No 1829/2003 of the European Parliament (InfoCuria, 6 September 2012).

The ECJ ruling arose from a request by Italy's State Council re a legal dispute between Dupont Pioneer Hi-Bred Italia and the Italian Ministry of Agriculture (MOA). DuPont submitted a request to override the decision of the MOA which refused to consider DuPont's application for approval to plant biotech maize in Italy, more specifically MON 810 Bt maize which is already listed in the EU common catalogue of varieties. EuropaBio noted that the ruling confirms again that national bans on biotech crops in EU countries are not legal. France, the largest EU maize producer, banned MON 810 maize in March 2012 but this decision was not endorsed by EFSA nor France's Conseil d'Etat, France's highest court of law. Countries with biotech crop bans will now have to react to the ruling. Following the announcement of the ruling, the Prime Minister of France declared that it would retain the temporary ban, which disappointed French farmers who have used the technology and recognize its value. It is ironical that the EU national governments which have banned biotech crops are in contradiction with EU law which they have agreed to as members of the EU.

GM Wheat Field Trial for Aphid Resistance

Wheat is the most important crop in the UK valued at ~US$2 billion annually. Wheat is attacked by cereal aphids (greenfly and black fly). The aphids suck sap from the crop and causes damage which results in loss in yield. Consequently a significant proportion of wheat in the UK has to be sprayed with insecticides to control the aphids and this result in some pesticide residues in wheat grain used as food (Food Navigator Sarah Hills, 6 April 2012). The biotech wheat has a dual action defense mechanisms against aphids which act as alarm pheromones; they produce elevated levels of a naturally occurring odor, (E)-β farnesene, which repels aphids by warning them of danger, and the same repellant attracts natural predators of aphids, such as ladybirds. If successful this would be a very important development and result in a decrease or elimination of insecticide application to wheat, a major food crop. It would also eliminate or reduce pesticide residues in wheat grain, the second most important food crop in the world.

In September 2011, the UK's Department for Environment, Food and Rural Affairs (DEFRA) approved a land mark field trial of biotech wheat which has been genetically modified to resist crop-damaging aphids. The 1.3 hectare trial is being conducted between March 2012 and September 2013 at Rothamsted Research Station UK, the oldest agricultural research station in the world. DEFRA indicated that the field trial is an essential stage of continuing research and that the trial had "tight controls and had to go through a complex and detailed clearance process." The biotech wheat was surrounded by a wheat-pollen barrier of at least 2 meters wide of a different grain and no cereal plants were grown within 20 meters. During the year following harvesting of the biotech wheat, the area will be left unseeded and any "volunteer" plants killed. The National Farmers Union stated that more than 20 species of aphids attack U.K. crops, reducing yields and quality. The NFU chief of science and regulatory affairs adviser, Helen Ferrier, said that ***"the approval of the wheat trial was an exciting development, genetic improvement, enabling the plants to be more resistant to aphid infestation, is one important way to reduce unsustainable crop losses and reliance on pesticides, …genetic modification is one highly effective breeding technology that can make crops resistant to pests"*** (DEFRA, 16 September 2011). Details of the biotech field trials conducted in the UK are provided in http://www.defra.gov.uk/environment/quality/gm/.

DEFRA also authorized two different field trials on different types of biotech potato, one by Leeds University on nematodes and the other by Sainsbury Laboratory on potato late blight.

Field Trial of Nematode Resistant Potato

At Leeds University, research is focused on transgenic resistance to the most devastating nematode of potatoes, potato cyst nematode (PCN, *Globodera* spp) which is found in 50 to 80% of potato fields in the UK and estimated to cause annual losses worth over US$100 million per annum in Europe alone. The work is at the proof of concept stage and utilizes a plant based chicken egg white cystatin (CEWC) in conjunction with a CaMV35S promoter (www.fbs.leeds.ac.uk/nem/Potato.htm). Contained and field trials have already confirmed the usefulness of the transgenic technology for controlling potato cyst nematode. Some of the nematicides currently used in the UK include some of the most toxic of registered pesticides, and government policy is to replace them with more benign means of control which the new transgenic technology offers. These include: a promise of improved durability of resistance; a control method that is effective at all levels of infestation; and a control method that is easily and safely deployed by farmers. The major constraint, by far, is the herculean effort and the significant long term financial investment required of the University, to satisfy the demanding tasks and expense of gaining deregulation and approval to commercially deploy the technology.

Amflora Potato

An international group of scientists including some from the Scottish Crop Research Institute (2009) have sequenced the potato genome. This is an important achievement, given that potato is the third most important food crop in the world after rice and wheat, and will allow the development of biotech potatoes to be expedited in the EU in "speeding the breeding" initiatives. It is noteworthy that Bt biotech potato was one of the first successfully commercialized biotech crops in the USA and Canada in the 1990s. The prospect of approval of "Fortuna" potato, developed by BASF in Europe with an approval target of 2014, could well prove to be a very important development for the future of biotech crops in the EU. Both public and private institutions in the EU are now developing several new biotech potatoes with traits ranging from improved starch production, late blight disease resistance, bacterial disease resistance and nematode resistance. The potato resistant to late blight being developed by BASF is of particular significance. Russia is also involved in the development of Bt potatoes resistant to the devastating Colorado beetle pest. In summary, in the next five years, biotech potatoes could present an attractive and appropriate biotech product for consideration by the EU, which produces 20% of global production in intensive cropping systems requiring heavy and expensive pesticide applications for diseases such as the devastating late blight fungal disease which was the cause of the Irish famine in 1845. Biotech potatoes could substantially reduce the need for pesticides on crops which is entirely consistent with EU policy.

One of the first actions that **EU Commissioner for Health and Consumer Affairs, Mr. John Dalli,** took in 2010 was to approve the planting of the biotech potato "Amflora" developed by BASF from Germany; this was the first in 13 years following the approval of Bt maize MON 810 in 1998. Commissioner Dalli proceeded to present a proposal that would allow EU states to independently reject or approve products. His objective was to make EU approvals for biotech crops more efficient, more equitable, less bureaucratic and more transparent. However, there have been many objections from member states including questioning the legality of the proposal, despite it having been cleared at the outset by Mr. Dalli's lawyers. There are more than ten biotech crops waiting for EU approval to plant, including two varieties of biotech potato, one from BASF, another by Avebe from Holland, and a sugarbeet developed jointly by KWS from Germany and Monsanto. The EU member states of Austria, Greece and Italy have consistently denied approvals for planting or importing of biotech crops in the EU. Several of the countries exporting biotech crops, including the USA, Canada and Argentina won a 2006 WTO lawsuit that required the EU to ease approvals of biotech crops; under this WTO ruling these countries could require duties to be paid by the EU if the EU continues to block trade in biotech crops (New York Times, 11 November 2010).

Because of the GM regulatory policy and slow approvals in the EU, in January 2012, the company BASF from Germany, announced that it was discontinuing research and marketing of biotech crops for Europe and shifting it to the USA, but confirmed that it had submitted the regulatory dossier to EFSA for its biotech potato "Fortuna", resistant to late blight disease: the BASF plan is to make Fortuna available in Europe in 2014, subject to regulatory approval (http://www.basf.com/group/pressrelease/P-11-488).

In July 2012 Ireland's Environmental Protection Agency approved a field trial to be conducted by Teagasc (Food Development Agency) at Oak Park of a biotech late blight resistant potato. Teagasc estimates the annual losses to late blight, still the most important disease of potatoes in the world and the cause of the Irish famine in1845, at Euro 15 million for Ireland alone (Irish Times, 27 July 2012).

Political Support to Biotech Crops in the EU.

Whereas there is a great deal of ideological and political opposition to biotech crops in the EU, there is also some more progressive thinking.

In a very substantive report, published in October 2009, entitled ***"Reaping the Benefits – Science and the sustainable intensification of agriculture,"*** **The Royal Society,** the UK's most prestigious scientific academy, has recommended publicly-funded research of GM crop technologies. The report concludes that the application of both conventional and biotech technologies would allow northern Europe to become one of the ***'major bread baskets of the world'***. The UK Government's Chief Scientist, **Sir John Beddington** has endorsed biotech crops for the UK (Crop Biotech Update, 29 October 2009).

The UK Government's Foresight Report concluded that Britain must embrace GM crops or face serious food shortages in the future. The Report has had unusually strong support from Government, ministers, leading scientists and is consistent with the recommendations of the recent substantive report from the UK's prestigious Royal Society (Crop Biotech Update, 8 January 2010).

Speaking at the Oxford Farming Conference, after the publication of the Food 2030 Report, Sir John Beddington, the UK's Chief Scientist said, ***"GM and nanotechnology should be part of modern agriculture. We need a greener revolution, improving production and efficiency through the food chain within environmental and other constraints. Techniques and technologies from many disciplines ranging from biotechnology and engineering to newer fields such as nanotechnology will be needed"*** (Gray, 2009). Sir David King, the UK Government's former Chief Scientific Adviser is a strong advocate of biotech crops and cautioned that, ***"The world would need all the food it could get to feed over 9 billion people by 2050. We will only do this with the assistance of a third green revolution and GM technologies will be crucial in delivery of this"*** (Cookson, 2008).

In July 2012, the EU Commission's Chief Scientific Advisor Dr. Anne Glover, stated that genetically modified organisms (GMOs) are no riskier than their conventionally farmed equivalents (EurActiv, 24 July 2012). She further clarified that ***"there is no substantiated case of any adverse impact on human health, animal health or environmental health, so that's pretty robust evidence, and I would be confident in saying that there is no more risk in eating GMO food than eating conventionally farmed food,"*** – as a result she concluded that ***"the precautionary principle no longer applies."*** Dr. Glover emphasized that she was not promoting GMOs, and added that ***"eating food is risky – most of us forget that most plants are toxic, and it's only because we cook them, or the quantity that we eat them in, that makes them suitable."*** She called for countries impeding GMO use ***"to be put to proof."*** She opined that scientific evidence is needed to play a more prominent role in policymaking on GMOs, and concluded that ***"I think we could really get somewhere in Europe if when evidence is used partially, there were an obligation on people to say why they have rejected evidence."*** Since her appointment as Chief Scientific Advisor to the EU in December 2011, this is by far the strongest endorsement of GMOs emanating from the EU and is a clear challenge to EU countries, like France, which have banned biotech crops despite their clearance by the EU's own European Food Safety Agency (EFSA).

UK environment secretary Owen Paterson expressed his opinion on biotechnology in an interview conducted in December 2012, saying that ***"Empathically, we should be looking at GM… I'm very clear it would be a good thing,"*** He also stressed that consumers were already eating GM food for sometime, with 160 million hectares of GM crops being grown globally. And thus, GM food should be grown and sold widely in the UK. Concerns about the health implications of GM crops are "a complete nonsense" according to the UK environment secretary (Crop Biotech Update, 12 December 2012).

Zero Tolerance Issue in the EU

The long debate about zero tolerance of unauthorized biotech crop events in imported feed has resulted in some progress with the approval of the following new EC Regulation 619/2011 on low level presence approved by the EU in 2011: ***"A feed material, feed additive or, in the case of compound feed, each of the feed material and feed additive of which it is composed shall be considered as non-compliant with Regulation (EC) No. 1829/2003 when the analytical result (x) for one measured transformation event minus the expanded measurement uncertainty (U) equals or exceeds the level of 0.1% related to mass fraction of GM material."*** The European Compound Feed Manufacturer's Federation (FEAC) was involved in this debate for a very long time, seeking a sensible concession similar to that granted to banned veterinary antibiotics, which are now allowed in the EU at trace levels. FEAC reasoned, quite rationally that the matter was of paramount importance given that soybean meal is the "lifeline" of Europe's livestock industry, and without it there would be "no" compound feed. The impractical zero tolerance policy had high risks because the EU is dependent for more than 80% on imports of vegetable proteins, for which there are no substitution possibilities in the short term (Crop Biotech Update, 5 November 2010).

EU's Points to Consider in Hastening GM Crop Adoption

In August 2012, Strategie Grains (Reuters, 16 August 2012) lowered its forecast for EU grain maize production by 7.1 million tons to 58.1 million tons, 13% below 2011. Maize production was significantly lower in central and southern Europe with reductions of 2 million tons each for the three major producers of Hungary, Italy and Romania. Considering the drought in the US, the Balkan region and the Black Sea countries, world maize production in 2012 /13 was forecast to be reduced by 70 million tons to 829 million tons.

Sales of organic food in the United Kingdom have decreased by 21% since the price of food spike in 2008 according to the pro-organic Soil Association, whilst retail food prices have increased by 25% since 2008; shoppers are now eliminating non-essentials as they have to spend 16% of their income on food (The Economist, 23 June 2012).

Petitions from biological scientists in Sweden and the UK

In October 2011, 41 leading Swedish biological scientists, in a strongly-worded open letter to politicians and environmentalists, spoke out about the need to revise European legislation to allow society to benefit from GM crops developed on science-based assessments of the technology. They stressed that current ***"European legislation in the field of genetic engineering is so narrow that it blocks the ability of researchers to take progress from publicly-funded basic research on plants through to practical applications."*** The scientists ***"urged politicians and environmental groups to take the necessary steps to change the relevant legislation so that all available knowledge can be used to develop sustainable agricultural and forest industries"…*** they declared that ***"the use of GM plants is both standard practice and necessary."*** Furthermore, they stated that ***"there is no scientific uncertainty on the issue of whether GM crops pose more risk to consumers or the environment than conventionally produced crops varieties. The legislation was formulated when there was not yet sufficient data on this but now we know better. Five hundred independent research groups have received 300 million Euros from the EU to study the risks. The conclusion in a summary of the results ("A decade of EU-funded GM research") is that GMOs are not per se more risky than conventional plant breeding technologies. We are basic research scientists and we know that the changes produced by genetic engineering are easier to control than those produced in other ways. The legislation argues the opposite, and imposes controls only on GM plants. The Swedish environmental movement has a proud tradition of working from a sound scientific basis. For many of us, an early involvement in the non-profit environmental movement was an essential element in choosing our current careers; we wanted to contribute to a better world. The environmental movement should view it as a warning that many of us, with sadness, abandoned it when we felt we could no longer belong to organizations that sided with anti-science and populist forces – without subverting our scientific principles. We urge the Swedish environmental movement to unite with science and act as a rational, informed voice to influence their more vocal foreign counterparts. Changing the genetic engineering legislation is not only a very important issue for Europe. Poorly funded plant breeding researchers and organizations in many third world countries are also being deprived of one of their best tools to provide better***

local crops because of the obvious risk of being excluded from the GM-hostile European market. We therefore urge our politicians to change this outdated law. Our desire is that the world's farmers will be offered seeds that have been developed to provide the most energy- and water-efficient and chemical-free agriculture and forestry as possible, but current genetic engineering legislation prevents this" (Tribe, D 2011; EU Commission, 2010).

Scientists in the UK endorsed the Swedish initiative and gained support for the following petition ***"We, the undersigned, share the views of 41 leading Swedish plant scientists (that current legislation of GM crops is not based on science, ignores recent evidence, blocks opportunities to increase agricultural sustainability and stops the public sector and small companies from contributing to solutions. We call on pressure groups and organic trade associations to cease and desist from blocking genetic solutions to crop problems, and on Europe to change current laws and adopt science-based GM regulations"*** (Tribe, D 2011).

Public Opinion of GM Crops in the UK

Public opinion in the UK has changed in favor of allowing GM/biotech field trials, according to a ComRes survey for *The Independent* (AGProfessional, 26 July 2012). The survey indicated that opposition to biotech crops is receding in Britain. Those surveyed were asked if the government should encourage biotech/GM crop experimentation in order to reduce the quantity of pesticides applied on to crops. Around 64% concurred that there should be experimentation, while 23% disagreed and 9% replied "didn't know."

Further analysis of the survey data shows that the views of men and women were different with 70% of men encouraging experimentation compared with 58% of women. Scientists in the UK including the UK's Chief Scientist, Sir John Beddington, and the apex scientific organization, the Royal Society are in favor of GM field trials. The Chief Scientist for the EU, Dr. Anne Glover, is also in favor of experimentation with GM which, based on scientific evidence, she considers as safe as conventional crops.

The study was conducted a few months after demonstrators threatened to destroy a GM wheat trial at Rothamsted Research Institute, but only a few demonstrators attended and they were unable to enter and realize their threat to destroy the GM wheat trial. The event was viewed as a victory for scientists in favor of GM field trials in the UK (Food Navigator Sarah Hills, 6 April 2012).

Public concern in the UK over biotech crops has decreased during the past ten years according to a recent survey (The Guardian, 9 March 2012) commissioned by the British Science Association. One quarter of people surveyed are now unconcerned about biotech crops compared with 17% ten years ago. The percentage of people "concerned" about biotech crops has also decreased by 5% from 24 to 17%. In the UK, political will in support of biotech crops is at a high level, with the agriculture minister Jim Paice informing farmers in January 2012 that biotech crops "could massively help food production", and Labor's shadow environment minister, Mary Creagh, proposing more money for biotech crop research. The DEFRA Minister Carolin Spelman also stated that growing biotech crops was probably going to be considered as an element to counter drought which affected south-east England in early 2012. Spelman had earlier indicated that the current government would be pro-biotech crops if managed effectively.

Sir John Beddington, the UK's Chief scientist, has acknowledged that whereas biotech crops are not a panacea they can make an important contribution to any food security strategy. The All Party, Parliamentary Committee Science and Technology in agriculture chair is also of the opinion that now is the appropriate time for the UK to re-open the debate on biotech crops in the UK. Professor Maurice Moloney, Chief Executive of Rothamsted Research Institute, has called for more engagement with the UK public on the benefits of biotech crops. The large number of 'neither agree nor disagree' opinion indicates that scientists need to engage with the UK public if the UK is to benefit to the same extent as the other countries globally which currently plant biotech crops commercially. The survey indicates that the UK public needs more information on the benefits and risks. Nearly half (44%) indicated that they did not know if biotech crops would be good for the British economy, while approximately the same percentage (48%) indicated that they did not know if biotech crops would be safe for future generations. Whereas political will has increased significantly in the UK, following the cessation of commercial activities by BASF, the UK now lacks a major biotech crop such as "Fortuna" – the biotech potato resistant to the devastating late blight disease, capable of delivering before 2015, major and sustainable economic, and environmental benefits assigned high priority in the EU. Another candidate is herbicide tolerant sugarbeet which could be made available by 2015 subject to regulatory approval. In September 2012, the UK Government published its response to the Environmental Audit Committee report on sustainable food (Farminguk.com, 13 September 2012). The Government dismissed the Committee's recommendation for additional controls on the growing of GM crops in the UK, and reaffirmed its support for a science-based approach to policy-making on agricultural biotechnology.

The support for biotech crops in the UK in early 2012 coincided with Denmark, in its role as revolving President of the EU, tabling a proposal to allow member states to ban the cultivation of GM crops on a country-by-country basis, whilst allowing other countries to go ahead with approval and commercial planting of biotech crops. The proposal was politically blocked and defeated with Germany and France leading the opposition group of countries and the UK, not endorsing the proposal because it was concerned that it could not meet WTO requirements.

In a 2011 survey commissioned by the UK's Crop Protection Agency (Crop Protection Agency UK Booklet, 2011), increased support for biotech crops was evident. More specifically, 35% supported placing GM foods on shelves in the UK: this figure increased to 37% if they were nutritious; to 44% if they helped to keep the price of food down; to 46% if biotech crops were also good for the environment, and to a high of 78% if biotech crops helped the UK become more self-sufficient in food.

GM Support From Denmark

The former **Danish Minister of Agriculture, Eva Kjer Hansen** published a welcomed report entitled ***"Let's get rid of the myths of GMOs"*** (Ministry of Agriculture and Fisheries, Denmark 2009). She called for an evidence-based open-debate on genetically modified organisms and argued that there is nothing new in modifying plant genetic material. She pointed out that recombinant insulin was accepted and used daily around the world and that there are biotech crops such as blight-resistant potatoes that offer Denmark significant advantages, including substantial reduction in pesticides with positive implications for the environment (potatoes are sprayed up to 7 times a season for late-blight control in Denmark) and biodiversity. She also cited benefits related to reductions in greenhouse gases. Denmark's forward-looking policy on biotech crops has anticipated that the country will plant biotech crops that offer Danish farmers advantages and that these could become available soon. Around 250 Danish farmers have already undertaken training in the practical implementation of coexistence practices so that they are prepared for planting the first commercial biotech crops determined to be safe and beneficial to Denmark.

GM in Switzerland

In a national referendum in 2005, Switzerland banned GM products with the most restrictive law which will expire and be reviewed again in 2013. As a result the Swiss have no direct experience with GM foods, except when they visit countries that market GM products, like Canada and the US in North America, where 70% of the processed food they consume are biotech A recent study in Switzerland offered three clearly labeled corn bread, organic, conventional, and GM to consumers at market stands. The authors concluded that consumers "treated the GM product like any other novel food and that consumers appreciated transparency and freedom of choice" and recommended that "retailers should allow consumers to make their own choice and accept the fact that not all people appear to be afraid of GM food. Interestingly, out of 3,750 customers only 2% of the responses were registered by the selling groups as negative to the choice available, whereas 53% were neutral and 45% were positive. This indicates that the emotionality of the public debate stands in strong contrast to the pragmatic behavior of consumers at the market stand (Aerni et al. 2011).

EC Compedium on Safety

In December 2010, the European Commission (EC) published a compendium "A Decade of EU-funded GMO Research (2001-2010)" which summarized the results of 50 research projects addressing primarily the safety of GMOs for the environment and for animal and human health. The compendium reported that the European Union (EU) has funded a significant number of projects on GMOs worth €200 million or US$250 million between 2001 and 2010 and invested over €300 million on research on the bio-safety of GMOs since 1982. Launching the compendium, the **European Commissioner for Research, Innovation and Science Máire Geoghegan-Quinn** said ***"The aim of this book is to contribute to a fully transparent debate on GMOs, based on balanced, science–based information. According to the findings of these projects GMOs potentially provide opportunities to reduce malnutrition, especially in lesser developed countries, as well as to increase yields and assist towards the adaptation of agriculture to climate change. But we clearly need strong safeguards to control any potential risks"*** (European Commission, 2010).

This new publication aims to contribute to the debate on GMOs by disseminating the outcomes of research projects to scientists, regulatory bodies and to the public. It is a follow-up to previous publications on EU-funded research on GMO safety. Over the last 25 years, more than 500 independent research groups have been involved in such research. According to the projects' results, there is, as of today, no scientific evidence associating GMOs with higher risks for the environment or for food and feed safety than conventional plants and organisms (European Commission, 2010).

Farmer Testimonies and Views

Jim McCarthy, who has an extensive farming business in Ireland, the US, Eastern Europe and Argentina, said ***"GM crops would allow EU farmers to use less agrochemicals and help them lower production costs. GM was the biggest development in agriculture since the tractor"*** (McCarthy, 2010).

Brief Chronological Overview of crop biotech related events in Europe in 2012 reported in ISAAA's weekly Crop Biotech Update (CBU), where original reference is provided:

1. A four year EU project, named AMIGA was launched to evaluate the impact of GM crops in Europe. The project activities include case studies on maize, and potato the only two GM crops GM crops currently approved for cultivation in Europe (Crop Biotech Update, 9 December 2011).

2. An EU survey on attitudes of EU farmers to herbicide tolerant GM crops concluded that they judge the technology based on its capability to deliver economic benefits, reduce cost of production; coexistence was viewed negatively by farmers (Crop Biotech Update, 21 Dec 2011).

3. A review article on field trial regulations in Europe reports that the European Union probably has the most stringent regulations in governing field trials. It was recommended that EU should demonstrate that the risk linked to GM crops has been "reduced to the level where it is regarded as acceptable within the narrowly defined limits of the regulations developed and enforced by national and regional governments, that is, there is no greater risk than growing an equivalent conventional crop" (Crop Biotech Update, 10 February 2012).

4. The European Food Safety Authority (EFSA) released the scientific opinion on the continued marketing of insect resistant and herbicide tolerant cotton (MON 531 x MON 1445) for food and feed use. Risk assessment showed that there were no biologically relevant differences in the compositional, phenotypic, and agronomic characteristics of GM cotton compared to its conventional counterpart (Crop Biotech Update, 30 March 2012).

5. Food and Drink Federation (FDF) President Jim Moseley called on Europe to rethink genetic modification (GM) technology. He issued a plea to politicians and consumers in Europe to consider the merits of GM technology saying that with over one billion people going to bed hungry at night, the United Kingdom and Europe should start the debate about new technologies such as GM (Crop Biotech Update, 4 April 2012).

6. An Economic Impact Assessment of Turkey's Biosafety Law finds that the way in which this law is being implemented has resulted in substantial negative economic impacts for the important Turkish importing feed and food manufacturing and livestock production sectors (Crop Biotech Update, 4 May 2012).

7. The Russian government has recently put in place the "Complex Program of Biotechnology Development in Russia (2012 – 2020)" with the signing of Russian Prime Minister Vladimir Putin. The biotech program, funded at US$40 billion over 8 years, aims to put Russia in a leading position in ag-biotechnology with improved biotech crops and to make the country competitive globally in bio-economy, nanotechnology and information technology (Crop Biotech Update, 4 May 2012).

8. A team of EU-funded researchers from Denmark, Germany and Spain has developed a new method to keep the unwanted glucosinolate toxins in oilseed rape from getting into the edible parts of the plant. The toxin-free oilseed rape is an important feed crop (Crop Biotech Update, 29 August 2012).

Progress with Biotech Crops in Africa

The continent of Africa remains the region to monitor in terms of growth potential for commercialization of biotech crops, based on the extent of R&D activities focused on pro-poor priority crops. Four countries – South Africa, Burkina Faso, Egypt and for the first time in 2012, Sudan, have already commercialized biotech crops. The map of Africa (Figure 34) provides a self-explanatory summary of the four countries commercially growing biotech crops and seven (including the commercial countries) conducting field trials with biotech crops in 2012. These are: Burkina Faso, Cameroon, Egypt, Kenya, Nigeria, South Africa and Uganda. The key crops, at various stages of experimentation in both confined and open trials, include banana, cassava, cotton, cowpea, maize, rice and sweet potato. Cameroon became the 7th country to join the group conducting field trials in 2012, by initiating the first biotech cotton trial in the country. It is important to note that in Cameroon, cotton occupies third place among industrial products, contributes 11% to added value in the manufacturing sector, and represents 9.5% of industrial production. Improving cotton productivity therefore has potential to positively impact millions of lives that depend on the many services in the cotton sub-sector value chain. Malawi continued pursuing various options for initiating biotech cotton trials and approval was granted in 2011.

Importantly, most of the on-going trials have focused on traits of high relevance to challenges facing Africa such as drought, nitrogen use efficiency, salt tolerance and nutritional enhancement, as well as resistance to tropical pests and diseases. Examples include drought tolerant maize through the Water Efficient Maize for Africa (WEMA) project with multiple trial seasons in three countries (Kenya, South Africa and Uganda); nitrogen and water use efficiency and salt tolerant rice in Uganda; cassava with increased pro-vitamin A, iron and proteins through the BioCassava Plus project in Kenya and Nigeria; the Africa Biofortified Sorghum (ABS) with enhanced Vitamin A levels, bio-available zinc and iron in Kenya and Nigeria; nutritionally enhanced banana with iron and pro-Vitamin A in Uganda; bacterial wilt resistant and banana parasitic nematode resistance in Uganda; and insect resistant cowpea in Burkina Faso and Nigeria.

The expanding number of confined field trials is a consequence of achieving promising results and an indication that Africa is progressively moving towards adopting important food security biotech crops. The research and field trial studies were conducted under the aegis of existing legislation or stand-alone biosafety structures.

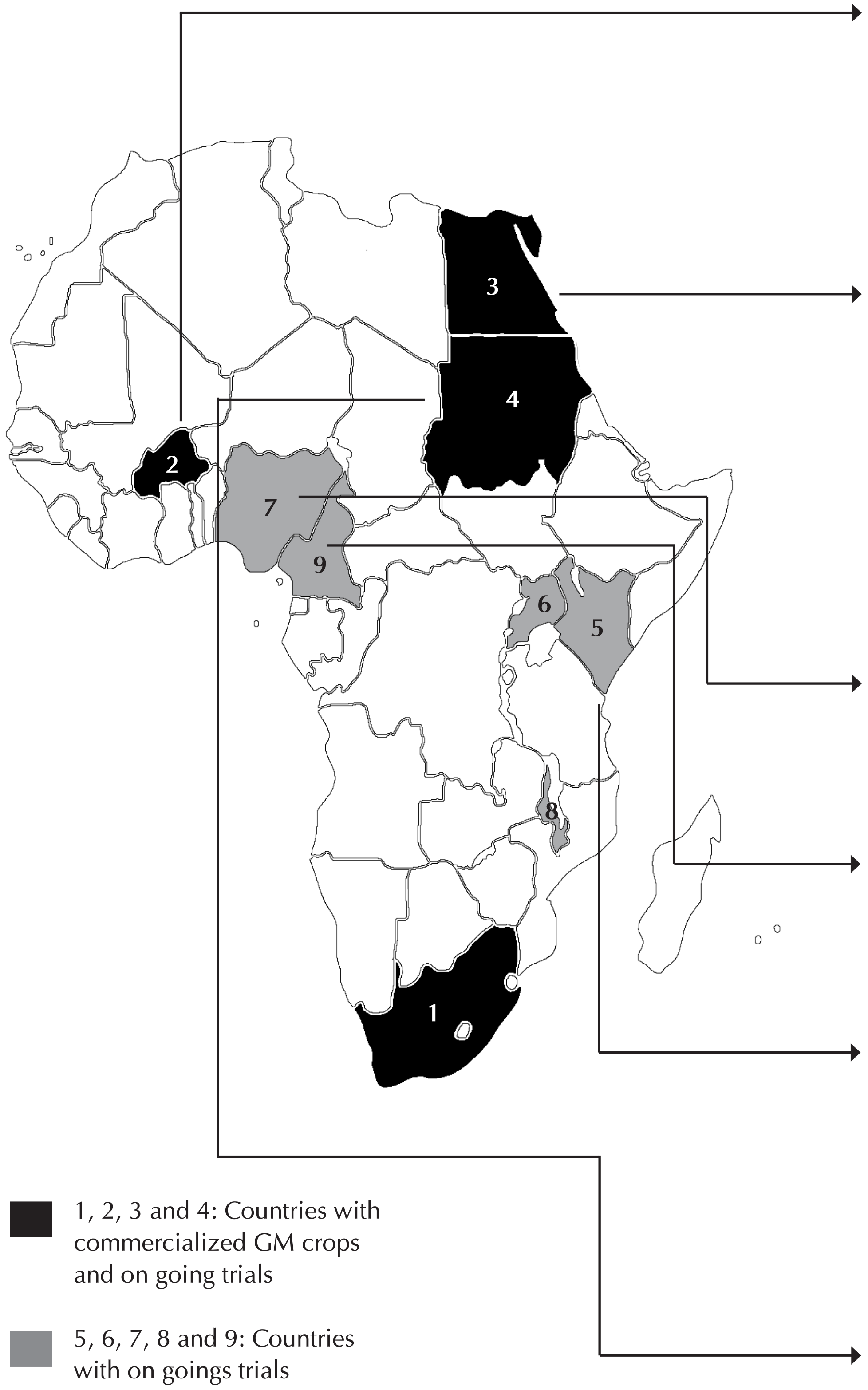
A diverse range of policy pronouncements in support of biotechnology and regulatory capacity development efforts also intensified in 2012. The formation of a High Level Advisory Panel on Science, Technology and Innovation by the African Union (AU) in July 2012 is a demonstration by African leaders of a burning desire to fully embrace advancements in science, technology and innovation for spurring development and poverty alleviation. The AU's Consolidated Plan of Action has one of its foci, on safe development and application of biotechnology and the building of a common African strategy for biotechnology. As the movers of the AU agenda, African Heads of State and Governments attending the Global African Diaspora Summit in Johannesburg, South Africa in May 2012, resolved to promote agricultural research and biotechnology in Africa. Further, the President of Malawi, Her Excellency Joyce Banda, in a "State of the Nation" speech to parliament, on 18 May 2012, endorsed the use of modern biotechnology in the country's plan to spur agricultural productivity. The Head of State noted: ***"With modern biotechnology, farmers will not be troubled to weed their gardens; they will not have to buy pesticides; and genetic modification will help improve soil carbon and moisture content."***

Ministers from 24 African states have endorsed the use of biotechnology to address the persistent food insecurity and poverty across the continent. During the 2nd Annual Dialogue of Ministers of Agriculture, Science and Technology meeting in Ghana, the ministers issued a joint declaration to the effect that Africa must apply cutting edge science to spur agricultural productivity. The meeting which was convened by the Government of Ghana and the Forum for Agricultural Research in Africa (FARA) to share ideas and agree on collective actions towards enhancing agricultural productivity in Africa.

In the area of biosafety legislation, the Ghanaian President successfully promulgated the assent of the Biosafety Law, initially debated and passed by parliament to govern activities related to commercialization of biotech crops in the country. Development of practical implementing regulations has been initiated to expand research and commercialization of biotech crops, more specifically cotton, cowpea and rice. The Government of Ghana, in cooperation with UNIDO, organized an expert group meeting in June 2012 to increase public awareness about appropriate options to increase cotton productivity, including the benefits deriving from use of modern biotechnology-based insect resistant and herbicide tolerant cotton. The meeting also served in facilitating an informed decision on the way forward for improving cotton productivity, through science-based considerations. An exposé on the benefits, lessons learned and experiences of farmers from countries already producing Bt-cotton including neighboring Burkina Faso, South Africa and India featured prominently. Ghanaian farmers have been keenly watching over their counterparts in Burkina Faso and have asked the government to fast-track access to the technology. On its part, the Government of Ghana is negotiating with a number of partners to bring the benefits of Bt cotton to farmers and to increase the competitiveness of the cotton sector.

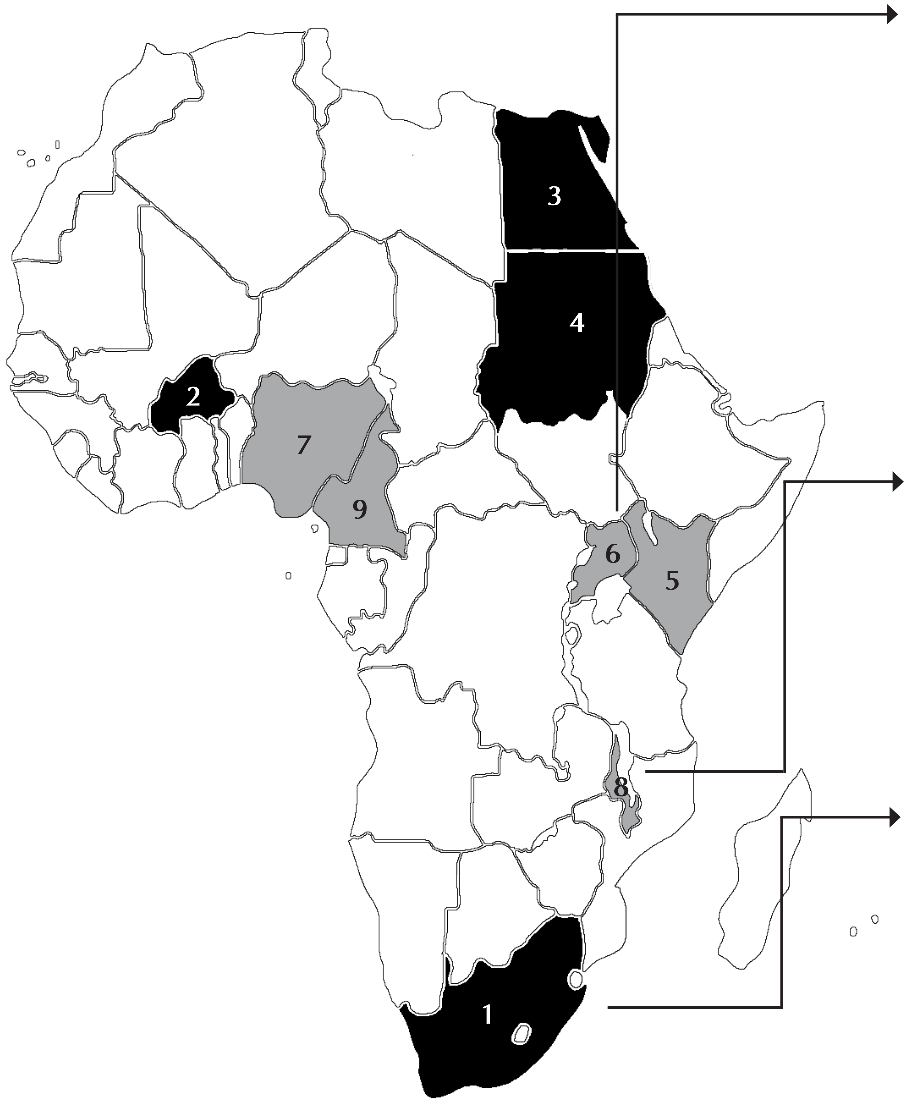
In Kenya, efforts to accelerate commercialization of biotech cotton by 2015 intensified, following completion of essential research by Kenyan researchers. Training of extension service staff and provision of research support on stewardship issues were conducted in the major cotton growing areas of Rift Valley, Nyanza and Western regions of the country. The activities are spearheaded by a commercialization task force that has developed a roadmap outlining the key activities and players

Figure 34. Summary of Biotech Crop Commercialization and Field Trials in Africa as of December 2012



Country	Crop	Trait	Institutions involved	Stage as in 2011
Burkina Faso Bt cotton commercialized in 2008	Cowpea, *Vigna unguiculata*	Insect resistance	INERA, AATF, NGICA, CSIRO, PBS, Monsanto	CFT - 2nd season
	Metarhizium robertsii (genetically modified fungus)	Controlling population of the mosquito *Anopheles gambiae*	Centre Muraz (Burkina Faso) in collaboration with the University of Maryland (USA) and the University of Johns Hopkins (USA)	Permission granted for CFT – 1st season in 2012
Egypt Bt maize approved for commercialization in 2008	Maize, *Zea mays* L.	Insect resistance	Monsanto	Open Field trials - 4th season
	Cotton, *Gossypium barbadense*	Insect resistance	ARC	Open Field trials F11 stage waiting approval
	Wheat, *Triticum durum* L.	Drought tolerance/salt tolerance	AGERI	Postponed for next year due to security reasons in East of Egypt
		Fungal resistance	AGERI	Open Field Trials - 3rd season
	Potato, *Solanum tuberosum* L.	Viral resistance	AGERI	Postponed for next year due to lack of funds
		Insect resistance	AGERI	Postponed for next year due to lack of funds
	Tomato, *Lycopersicon esculentum*	Viral resistance	AGERI, Cairo University	CGH - 2nd season
	Tomato, *Lycopersicon esculentum*	Salt tolerance	Cairo University	CGH - 1st season
	Sugarcane, *Saccharum officinarum*	Insect resistance	AGERI, Cairo University	Experimental field trial - 2nd season
		Fungal resistance	AGERI	Experimental field trial - 2nd season
	Rice, *Oryza sativa*	Insect resistance	Cairo University	CGH - 2nd season
	Strawberry, *Fragaria ananassa*	Viral resistance	Cairo University	CGH - 1st season
Nigeria Biosafety Law passed in 2011, awaiting Presidential assent	Cassava, *Manihot esculenta Crantz*	Biofortified with increased the level of beta-carotene, provitamin A	National Root Crops Research Institute	CFT 2nd season completed
	Cassava, *Manihot esculenta Crantz*	Biofortified for increased iron level	National Root Crops Research Institute	CFT – 3rd season has been completed a new CFT has just commence)
	Cowpea, *Vigna unguiculata*	Insect resistant against Maruca pest	AATF, Institute of Agricultural Research	CFT - 3rd season
	Sorghum (ABS), *Sorghum bicolor Moench*	Enhanced Vit A levels, Bioavailable Zinc and Iron (Enhanced with protein digestibility, greater bio-availability of zinc and Iron and pro-vitamin A content)	Africa Harvest, Pioneer Hi-Bred, a company of DuPont business, IAR and NABDA	CFT – 1st season planted, (Currently undergoing back crossing with preferred Nigerian variety)
Cameroon	Cotton *Gossypium hirsutum* L.	Insect resistance	Bayer	CFT - 1st season
Kenya Biosafety Act approved in 2009 3 sets of Biosafety implementing regulations published in 2011 Labeling regulations published in 2012	Maize, *Zea mays* L.	Drought Tolerance (WEMA)	AATF, CIMMYT, KARI, Monsanto	CFT - 2nd season
	Cotton, *Gossypium hirsutum* L.	Insect resistance	KARI/Monsanto	CFT - 5th season
	Cassava, *Manihot esculenta Crantz*	Cassava mosaic disease	KARI, Danforth Plant Science Center (DDPSC)	CFT - 1st season
		BioCassava Plus Vitamin A enriched	KARI, DDPSC, IITA, CIAT,	CFT - 1st season
	Sweet potato, *Ipomoea batatas*	Viral diseases	KARI/Monsanto	CFT - 1st season
	Sorghum (ABS), *Sorghum bicolor Moench*	Enhanced Vit A levels, Bioavailable Zinc and Iron	Africa Harvest, Pioneer Hi-Bred, a DuPont business and KARI	Approved for Contained Greenhouse trial by the NBA
	Pigeon pea	Insect resistance	Kenyatta University	Lab and Greenhouse transformation approved by NBA in March 2011
	Sweet potato	Insect resistance	Kenyatta University	Lab and Greenhouse transformation approved by NBA in April 2011
Sudan Commercialized Bt cotton in 2012	Cotton	Insect resistant		

Figure 34. Summary of Biotech Crop Commercialization and Field Trials in Africa as of December 2012 (continued)



■ 1, 2, 3 and 4: Countries with commercialized GM crops and on going trials

▨ 5, 6, 7, 8 and 9: Countries with on goings trials

Country	Crop	Trait	Institutions involved	Stage as in 2011
Uganda	Maize, *Zea mays L.*	Drought tolerance	NARO, AATF, Monsanto	CFT*, 3rd season
		Insect resistance	NARO, AATF, Monsanto	CFT applications submitted to IBC/NBC
	Banana, *Musa*	Bacterial wilt resistance	NARO, AATF, IITA	CFT - 3rd cycle
		Nutrition enhancement (Fe and Pro-vitamin A)	NARO, Queensland University of Technology	CFT - 3rd planting
		Banana parasitic nematode resistance	NARO, University of Leeds	CFT - planted August
	Cassava, *Manihot esculenta Crantz*	Virus resistance	NARO, DDPSC, IITA	CFT - 2nd season
		Cassava brown streak virus (CBSV) resistance	NARO, DDPSC, IITA	Multi location CFT application submitted to IBC/NBC
	Cotton, *Gossypium hirsutum L.*	Bollworm resistance and herbicide tolerance	NARO, Monsanto	CFT - Awaiting decision for multi-locational trials
	Sweetpotato, *Ipomoea batatas*	Weevil resistance	NARO, CIP	Contained Greenhouse trials on-going
		Sweetpotato feathery mottle virus (SPFMV) and Sweetpotato chlorotic stunt virus (SPCSV) resistance	NARO, CIP	CFT applications submitted to IBC/NBC
	Rice	Nitrogen and water use efficiency and salt tolerant rice	NARO, AATF	Planting expected in October 2012
Malawi	Cotton, *Gossypium hirsutum L.*	Bt and HT	Bunda University, Monsanto Ministry of Agric, Envi. Affairs Dept National Commission for S&T	CFT approved in August 2011, not yet planted
South Africa 1st Commercialized 1998	Maize, *Zea mays* L.	Drought tolerance	Monsanto	CFT Planted
		Herbicide tolerance	Pioneer Hi-Bred	CFT Planted
		Insect resistance		CFT Planted
		Insect/herbicide tolerance	Monsanto	CFT Planted
			Pioneer Hi-Bred	CFT Planted
	Cassava, *Manihot esculenta Crantz*	Starch enhanced	ARC-Industrial Crops Research Institute	CFT Planted in 2010
	Cotton, *Gossypium hirsutum* L.	Insect/herbicide tolerance	Bayer	CFT Planted
		Herbicide tolerance		
	Potato, *Solanum tuberosum* L.	Insect resistance	ARC-OVI	CFT
	Bulb Flower, *Ornithogalum dubius x thyrsoides*	Virus resistance	Agricultural Research Council-Vegetable and Ornamental Plants Institute	CFT Planted
	Sugarcane	Alternate sugar (rattoon) Increased yield and sugars Increased cellulose Increased yield and starch Decreased starch	South African Sugar Research Institute	CFT Planted
	Sorghum, *Sorghum bicolor*	Biofortified – Pro-vitamin A, protein, digestibility, iron and zinc	Africa Harvest, Pioneer, a DuPont business and CSIR	Contained Greenhouse Trials (CGH)

at each stage of the commercialization process from determination of suitable varieties in different agro-ecological zones to establishment of systems for seed multiplication and distribution to farmers. Members of the task force include all players in the cotton sub-sector value chain from researchers to ginners, regulators, service providers in extension, inputs supply, marketing and communications. This is an appropriate public-private sector partnership that is poised to deliver to Kenyan farmers, the long-awaited biotech cotton seeds by 2015. Introgression of the Bt genes into local and popular cotton varieties is ongoing while an application for multi-locational trials is under development.

The formation and launching of the Uganda Biotechnology and Biosafety Consortium (UBBC) to advance the cause of biotechnology in improving livelihoods is another strong indicator of growing acceptance of biotech crops in Africa. The consortium is a unique development and was born out of a strong need to form a multi-sectoral, multi-stakeholder competent organization that will bring together stakeholders around the common cause of biotech science advancement. It is a coalition of different stakeholders ranging from policy makers, scientists, private sector leaders, civil society organization leaders and government officers in their individual capacities as well as stakeholder agencies from both public and private sectors. Uganda boasts the highest number of biotech crop field trials in the Eastern Africa sub-region (see Africa map).

African farmers took center stage in urging their governments to help them access the technology. In September 2012 for example, the Zimbabwe Farmers Union and the Confederation of Zimbabwe Industries, called on Zimbabwe's government to end a ban on biotech crop production to achieve greater food security. They said: ***"We will continue pushing for the embracing of GMOs production using GMO technology for exports as a starting point"*** arguing that the nation would gain by adopting biotech food production. These sentiments were further corroborated with a powerful statement by the Ghanaian Minister for Environment, Science and Technology Hon. Ms. Sherry Ayittey who said ***"With biotechnology, there will be hope for numerous farmers on the continent. We can no longer stretch our hands to Europe for food aid. All leaders have to come on board and support biotechnology to make Africa food secure."***

Regional initiatives on harmonization of policies and regulatory frameworks to allow for cost-efficiency in the sharing of knowledge, expertise and resources were reinforced. After more than nine years, consultations among member states of the Common Market for Eastern and Southern Africa (COMESA) have produced draft policies and biosafety guidelines on GM technology, aimed at a regional approach to handling issues of commercial planting and trade in GM/biotech crops as well as access to food aid. Implementation of national consultations on the draft regional biosafety guidelines among member states was completed and a regional workshop conducted to validate the feedback. The policy guidelines now await endorsement by the COMESA Ministers of Agriculture, Environment and Natural Resources.

The regional harmonization process aims at sharing information, resources and expertise for cost-effectiveness in capacity building and drawing synergies to avoid redundancies. Under the proposals, a country which desires to grow a GM crop commercially would inform COMESA, which would then conduct a science-based risk assessment audit. The body would judge whether the crop is safe for the environment and human consumption. If the assessment proved positive, broader regional approval would be given for the crop to be grown commercially in all COMESA countries. National governments would however retain the power to decide whether or not to proceed. Concerning the regional initiatives, a regional scientific committee was nominated and in October, a meeting was scheduled to adopt the regional handbook of the procedures and methodological approaches for risk assessment and management of GMOs.

COMESA is the largest economic trading bloc in Africa. It has 19 member states, a collective population of 390 million people, an annual import trade of around US$32 billion, and an export trade of US$82 billion. Agriculture plays a big role in the economies of COMESA countries in terms of livelihood, employment and international trade. Agricultural commodities are therefore major drivers for growth in intra-COMESA trade. COMESA trade statistics indicate that total intra-COMESA trade during 2008 amounted to some US$6.3 billion. Of this, food and agricultural raw materials constituted US$2.1 billion. However, cyclical droughts and abiotic stresses in the region predispose these countries to food insecurity, while biotic challenges such as diseases and pests affect productivity of most staple crops. Adoption of biotech crops would thus make a significant contribution in increasing productivity, incomes and environmental conservation as well as contributing to alleviation of poverty.

In West Africa, a regional scientific committee was nominated to spearhead development of a regional handbook of the procedures and methodological approaches for risk assessment and management of GMOs in the sub-region. Such initiatives will greatly enhance sharing of risk assessment data and thus hasten the decision making process.

Brief Chronological Overview of crop biotech related events in Africa in 2012 reported in ISAAA's weekly Crop Biotech Update (CBU), where original reference is provided:

1. USAID granted a US$7 million grant to Uganda, in conjunction with Cornell University, to develop a biotech Matoke banana, (the principal staple in East Africa) resistant to pests nematodes and diseases like Black Sigatoka, which cause severe yield losses in Uganda (Crop Biotech Update, 2 December 2011).

2. The Drought Tolerant Maize for Africa (DTMA) project was recognized as the *"Best Technological Breakthrough"* during the UK Climate Week Awards. The project, which is being implemented by CIMMYT and IITA in 13 African countries, is funded by UK's Department for International Development, Bill & Melinda Gates Foundation (BMGF) with complementary

grants from the Howard G. Buffet Foundation (HGBF) and the United States Agency for International Development (USAID) (Crop Biotech Update, 30 March 2012).

3. Ugandan stakeholders urged the government to speed up the approval of the country's Biosafety Bill at a meeting organized by the NEPAD agency – African Biosafety Network of Expertise (ABNE) in collaboration with the Program for Biosafety Systems to share ideas and agree on collective actions towards enhancing agricultural productivity in Africa (Crop Biotech Update, 30 March 2012).

4. Uganda's National Agriculture Research Organization (NARO) through senior research scientist Dr. Yona Baguma, outlined a roadmap towards commercialization of Bt cotton by 2014, GM cassava in 2016 and drought resistant maize (WEMA) by 2017 (Crop Biotech Update, 13 April 2012).

5. Biotech experts from COMESA member states recommended for endorsement a draft regional policy to govern commercial planting, trade and access to emergency food aid with GM content in Eastern and Southern Africa. The draft policy is now awaiting endorsement by COMESA Ministers of Agriculture, Environment and Natural Resources (Crop Biotech Update, 18 May 2012).

6. The Bill and Melinda Gates Foundation granted a US$3 million grant to the Open Forum on Agricultural Biotechnology in Africa (OFAB). The OFAB was initiated by the African Agricultural Technology Foundation (AATF) to increase networking and awareness of modern biotechnology, for informed policy choices on safe and responsible adoption of genetically modified crops in Africa (Crop Biotech Update, 18 May 2012).

7. African Heads of State and Governments attending the Global African Diaspora Summit issued a joint statement resolving to promote agricultural research and biotechnology. The Summit was held in Johannesburg, South Africa on May 2012 (Crop Biotech Update, 1 June 2012).

8. The Director of cotton production and development at SOFITEX, a leading cotton company in Burkina Faso, Dr. Dehou Dakuo, re-affirmed the country's plan to increase production of Bt cotton. This followed a misleading report aired on Radio France Internationale (RFI) declaring that Burkina Faso was about to quit growing Bt cotton (Crop Biotech Update, 8 June 2012).

9. Togo's Permanent Secretary in the Ministry of Agriculture, Livestock and Fisheries, Mr. Kombaté Dindiogue Konlani acknowledged biotechnology as a valuable tool in addressing problems facing Togo's agriculture sector (Crop Biotech Update, 15 June 2012).

10. Prof. Calestous Juma, one of the world's most influential scientists in technological innovations, challenged Kenyan youth to utilize biotechnology to promote economic growth in the same way mobile technology has revolutionized money transfer and banking. He stressed the importance of agricultural biotechnology for Kenya as one of the solutions to the major challenges facing the country, such as fast-growing population = ecological degradation, and climate change (Crop Biotech Update, 22 June 2012).

11. Zimbabwe's Minister of Finance Hon. Tendai Biti urged the country's cotton farmers to adopt Bt cotton to enhance their production and financial returns from cotton farming. He advised farmers to learn from countries like India, which has become competitive through the use of biotechnology (Crop Biotech Update, 29 June 2012).

12. Cereal millers in Kenya raised concerns over stringent GMO labeling regulations published by the government through recommendation by Kenya's National Biosafety Authority judging them as too harsh, prohibitive and punitive to millers handling any GM cereals like maize (Crop Biotech Update, 29 June 2012).

13. The World Bank encouraged African countries to harmonize their biosafety regulations in a report published in June 2012. Citing ongoing regional harmonization initiatives by ECOWAS and COMESA, the report pointed out that regional harmonization would be useful especially in helping countries lacking sufficient human, institutional, and financial resources to operate a biosafety regulatory system (Crop Biotech Update, 3 August 2012).

2012 Authoritative Quotes on Biotechnology from Africa Leaders and Farmers

Burkina Faso:

Hon. Prime Minister of Burkina Faso Beyon Luc Adolphe Tiao in his speech on the state of the Nation on 29th March 2012 said that, ***"In the field of research and innovation, my government has managed, during the year 2011 to achieve substantial results in conducting further research on Bt cotton, to undertake research on Brazilian cotton and a wide range of species of Bt cowpea."***

Kenya

1. Prof. Margaret Kamar, Kenyan Minister for Higher Education, Science and Technology in a forum on 6th August, 2012: ***"Kenya is investing in biotechnology in order to maximize productivity in agriculture, industry, protection of the environment and conservation of biodiversity and so scientists need to be proactive and demystify public concerns with compelling evidence."***

2. Hon Prof. Ayiecho Olweny, Assistant Minister, Ministry of Education and Member of Parliament (23 February 2012): ***"Kenya has all the legal documents and structures to adopt GM technology. The adoption of GM technology will help the country experience the green revolution. In other parts of the world, farmers who have adopted GM crops are growing richer and richer than us as we remain hinged on arguments."***

3. Prof. Crispus Kiamba, Permanent Secretary Ministry of Higher Education, Science and Technology (2 April, 2012): ***"When we adopted the biosafety law the noise that followed was not from a scientific point of view especially in the social and political circles but as someone used to say "upende usipende" (you like it or not), we cannot avoid GMOs unless we want to be a supermarket for South African food imports which are genetically modified anyway."***

4. Prof. Calestous Juma (14 July 2012): ***"It's about time Africa cut out the rhetoric and looked at solid scientific evidence which actually show the benefits of adopting crop biotechnology. We should move on because science has already proven that GM crops aren't harmful to either human beings or the environment."***

Ghana

Ghana Minister for Environment, Science and Technology, Hon. Ms. Sherry Aryeetey (3 May 2012): ***"The global population is poised to increase up to 9 billion by 2050. Food security is threatened by loss of fertility of soils and long periods of drought because of climate change. Agricultural biotechnology is poised to influence agriculture globally and it offers a possibility to deal with those challenges."***

Dr. A.B Salifu, director of the Ghana Council for Scientific and Industrial Research (CSIR) (3 May 2012): ***"Africa cannot wait. We need to be on the biotechnology train in order to save our people from abject poverty."***

Malawi

Her Excellency the President of Malawi Dr. Joyce Banda in her maiden "state of the nation" speech to the parliament (18 May 2012): "***My government will encourage technology and innovation adaptation by promoting and supporting genetic modification in agriculture. With Modern biotechnology, farmers will not be troubled to weed their gardens; they will not have to buy pesticides; and genetic modification will help improve soil carbon and moisture content. Genetically modified foods are pests resistant; they require fewer chemicals and are normally drought resistant."***

Nigeria

Hon. Raphael Uzochi Igbokwe, Nigerian Member, House representative (June 2012): ***"My constituents are largely rural and more than 80% are subsistence farmers. It is my belief that when biotechnology is deployed to our agricultural system, my people will be better off."***

Tanzania

Permanent Secretary, Ministry of Agriculture, Food Security and Cooperatives Mr. Mohamed S. Muya (14 September 2012): ***"The Ministry believes that the use of genetic engineering could help in combating the agricultural challenges caused by climate change such as drought, infection and harmful pests, which among other things need insecticides to control them."***

Uganda

Uganda's Minister of State for Agriculture, Animal Husbandry and Fisheries Prof. Z. M. Nyiira (30 March 2012): ***"The Government has identified biotechnology as a tool that can help meet the goals of national development and contribute towards enhanced food security. Uganda supports the use of agricultural biotechnology as a component of its food security policies. It is time to allay fears that biotechnology is not safe."***

Zimbabwe

The Confederations of Zimbabwe Industries and Zimbabwe Farmers Union (8 September 2012): ***"Zimbabwe should do away with a GMO ban to attain food security. We will continue pushing for the embracing of GMOs production using GMO technology for exports to be a starting point."***

The aforementioned progress notwithstanding, a number of challenges were experienced in 2012 with a bearing on the political goodwill for biotech crops in Africa and require urgent attention. In Nigeria, for example, the anticipated presidential assent to the Biosafety Bill passed by parliament in 2011 is still on hold. The Kenyan cabinet in November 2012 issued a ban on importation of GM crops over what the Minister for Public Health and Sanitation stated as concerns over renewed debates on the safety of GM crops as well. An inter-Ministerial task force comprising experts from the Ministries of Public Health and Sanitation, Higher Education, Science and Technology and the National Biosafety Committee is under constitution to review implications of the ban and advise on the way forward. In Uganda, biotech cotton trials were put on hold as the partners set out to review varietal choices and devise new technology transfer modalities. This move will have an impact on the commercialization date for the crop at the detriment of thousands of cotton farmers. It is imperative that the issues are urgently addressed to avert further delay of safe and beneficial crop technologies to African farmers who need them most.

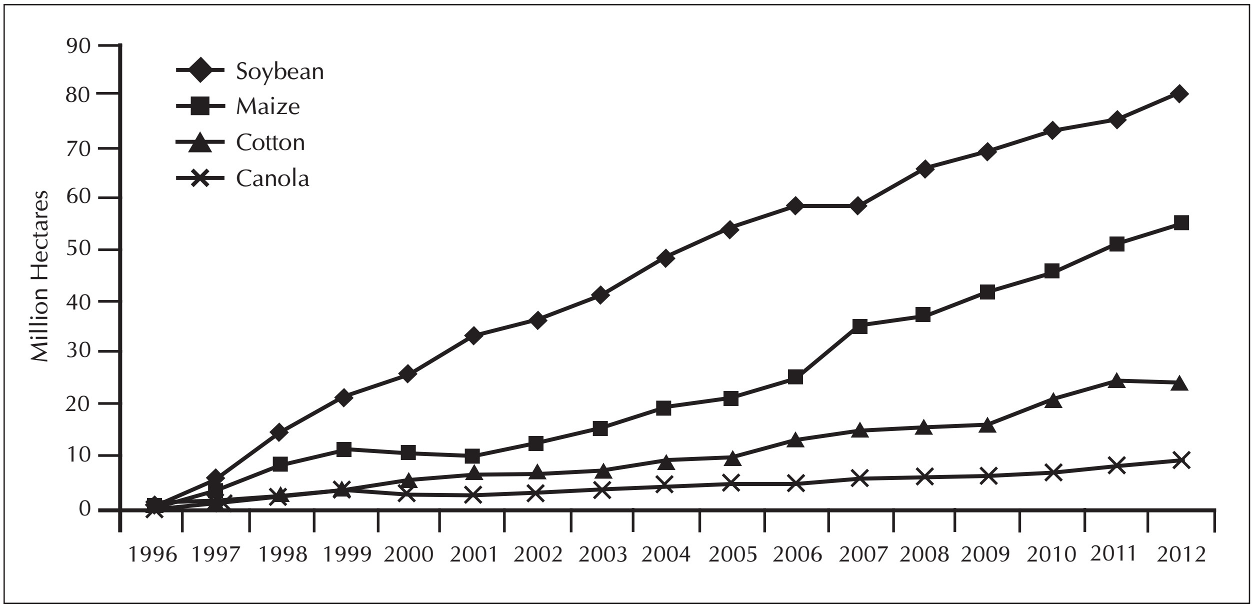
Distribution of Biotech Crops, by Crop

The distribution of the global biotech crop area for the four major crops is illustrated in Figure 35 and Table 39 for the period 1996 to 2012. It clearly shows the continuing dominance of biotech soybean occupying 47% of the global area of biotech crops in 2012; the entire biotech soybean hectarage is virtually herbicide tolerant, with a very small hectarage of the stacked product in Brazil for seed production. Biotech soybean retained its position in 2012 as the biotech crop occupying the largest area globally, occupying 80.7 million hectares in 2012, 7% higher than 2011; biotech maize had the second highest area at 55.1 million hectares and also had the second highest year-to-year absolute growth for any biotech crop at 4.1 million hectares. Upland biotech cotton reached 24.3 million hectares in 2012 down from the 24.7 million hectares grown in 2011. Canola reached 9.2 million hectares in 2012 with a 12% year-to-year global growth rate with record plantings of canola in Canada. Sugarbeet is a relatively new biotech crop first commercialized in the USA and Canada in 2007, and plateaued at 97% adoption rate in 2012, approximately the same adoption rate as 2010. RR®alfalfa, first grown in 2006, had a five year gap of no planting, pending legal clearance and then occupied ~200,000 hectares in 2011, equivalent to approximately 10 to 15% of the 1.3 million hectare seeded in the USA in 2011. In 2012, another estimated 250,000 were planted in 2012 for a total of 450,000 hectares. Small hectarages of biotech virus-resistant squash and papaya continued to be grown in the USA; China also grows about 5,000 hectares of PRSV resistant papaya and ~500 hectares of Bt poplar.

Biotech soybean

In 2012, biotech soybean accounted for 47% of all the biotech crop hectarage in the world and was grown in 11 countries. The global hectarage of herbicide tolerant soybean in 2012 was 80.7 million hectares, up by 5.3 million hectares, or 7% from 2011 at 75.4 million hectares. The increase resulted from intensified adoption in Brazil in particular. Modest increases were recorded in Canada, Paraguay, Uruguay, South Africa and Bolivia. There were 11 countries which reported growing RR®soybean in 2012. The top three countries, growing by far the largest hectarage of herbicide tolerant soybean, were the USA (29.5 million hectares), Brazil (23.9 million hectares) and Argentina (20.2 million hectares). The other eight countries growing RR®soybean in decreasing order of hectarage include Paraguay, Canada, Uruguay, Bolivia, South Africa, Mexico, Chile and Costa Rica. Of the global hectarage of 100 million hectares of soybean grown in 2012 (FAO, 2009), an impressive 81% or 80.7 million hectares were RR®soybean.

Figure 35. Global Area of Biotech Crops, 1996 to 2012: by Crop (Million Hectares)



Source: Clive James, 2012.

Table 39. Global Area of Biotech Crops, 2011 and 2012: by Crop (Million Hectares)

Crop	2011	%	2012	%	+/-	%
Soybean	75.4	47	80.7	47	5.3	+7
Maize	51.0	32	55.1	32	4.1	+8
Cotton	24.7	15	24.3	14	-0.4	- 2
Canola	8.2	5	9.2	5	1.0	+12
Sugar beet	0.5	<1	0.5	>1	– –	– –
Alfalfa	0.2	<1	0.4	>1	0.2	– –
Papaya	<0.1	<1	>0.1	>1	– –	– –
Others	<0.1	<1	>0.1	>1	– –	– –
Total	**160**	**100**	**170.3**	**100**	**+10.3**	**+6**

Source: Clive James, 2012.

The increase in income benefits for farmers growing biotech soybean during the 16-year period 1996 to 2011 was US$32.2 billion and for 2011 alone, US$3.9 billion (Brookes and Barfoot, 2013, Forthcoming).

Biotech maize

In 2012, 55.1 million hectares of biotech maize was planted – this represents an increase of 8%, equivalent to a 4.1 million hectares. It is noteworthy that 17 countries grew biotech maize in 2012. There were five countries which grew more than 1 million hectares of biotech maize in 2012 in decreasing order of hectarage they were: USA (34.1 million hectares), Brazil (12.1 million), Argentina (3.3 million), South Africa (2.4 million) and Canada (1.6 million hectares). The largest increase at the country level in 2012 was Brazil, up by almost 3 million hectares. Modest increases were reported by several countries. Five EU countries continued to plant a record 129,071 hectares of biotech Bt maize in the EU in 2012, equivalent to a 13% increase over 2011– this compares with 114,490 hectares in six countries in 2011. The five countries, in decreasing order of hectarage were Spain, Portugal, Czechia, Romania and Slovakia. No estimate was available for Poland although Bt maize was probably being planted, consistent with EU approval of Bt maize. An important feature of biotech maize is stacking, which is discussed in the sections on countries and traits.

Of the global hectarage of 159 million hectares (FAO, 2009) of maize grown in 17 countries in 2012, 35% or 55.1 million hectares were biotech maize; this compares with 32% or 51 million hectares grown in 16 out of 29 biotech crop countries worldwide in 2011. Preliminary projections of yield gains from biotech drought tolerant maize in the USA, expected to be available about 2013, or earlier, are 8 to 10% in the non-irrigated areas from North Dakota to Texas. By 2015, current yields of 5.5 metric tons in the dry regions of the USA are projected to increase by up to 7.5 metric tons per hectare.

As the economies of the more advanced developing countries in Asia and Latin America grow at much higher rates than North America and Europe, this will significantly increase demand for feed maize to meet higher meat consumption in diets, as people become wealthier and more prosperous with more surplus income to spend. Coincidentally, maize continued to be used for ethanol production in the US, estimated at 40% to 50% of total maize hectarage in 2012.

The increase in income benefits for farmers growing biotech maize during the 16 years (1996 to 2011) was US$30 billion and US$8.6 billion for 2011 alone (Brookes and Barfoot, 2013, Forthcoming).

Biotech cotton

With lower global price of cotton, the area planted to biotech cotton globally in 2012 was down by half a million hectares from a record 24.7 million hectares in 2011. A total of 15 countries grew biotech cotton in 2012 and four grew more than 1.0 million hectares, in descending order of hectarage, they are: India (10.8 million hectares), USA with (4.4 million hectares), China (4.0 million), and Pakistan (2.8 million hectares). Another 11 countries grew biotech cotton.

RR®Flex cotton was introduced in the USA and Australia for the first time in 2006 and widely grown in 2012. In 2012, biotech hybrid cotton in India, the largest cotton growing country in the world, occupied 10.8 million hectares of approved Bt cotton despite almost optimal levels of adoption which reached 93% in 2012. The advantages of Bt cotton hybrid in India are significant and the increase in 2012 was due to the significant gains in production, economic, environmental, health and social benefits, which has revolutionized cotton production in India. It is notable that, Burkina Faso which grew 8,500 hectares of Bt cotton (Bollgard®II) for the first time in 2008, increased this hectarage to 115,000 hectares in 2009 and to 247,000 hectares in 2011, and to over 300,000 hectares in 2012. India at 10.8 million hectares, USA (4.4 million hectares), China (4 million hectares) and Pakistan (2.8 million hectares) are the top four biotech cotton producing countries. Australia planted over 500,000 hectares of biotech cotton in 2012 after a peak hectarage of almost 600,000 hectares in 2011.

Based on a global hectarage of 30 million hectares (FAO, 2009), 81% or 24.3 million hectares, were biotech cotton and grown in 15 of the 28 biotech crop countries worldwide.

The increase in income benefits for farmers growing biotech cotton during the 16-year period 1996 to 2011 was US$32.5 billion and US$6.7 billion for 2011 alone (Brookes and Barfoot, 2013, Forthcoming).

Biotech canola

The global area of biotech canola is estimated to have increased by a significant 1 million hectares from 8.2 million hectares in 2011 to 9.2 million in 2012 with most of that gain coming from Canada. The US and Australia also had modest increases in biotech canola hectarage. Canada, by far is the largest grower of canola globally, has consistently increased reaching a record 98% in 2012 compared with 96% in 2011. Only four countries currently grow biotech canola: Canada, the USA, Australia and Chile but the global hectarage and prevalence could increase significantly in the near term in response to the likely increased use of canola for vegetable oil and biodiesel. Less than 1% of the canola crop in Canada was used for biodiesel in 2008 and this is expected to remain low at around 2% until 2012 when new biodiesel plants come on stream.

Of the global hectarage of 31 million hectares of canola grown in 2012, 30%, or 9.2 million hectares (up from 26% and 8.2 million hectares in 2011) were biotech canola grown in Canada, the USA, Australia and Chile.

The increase in income benefits for farmers growing biotech canola during the 16-year period 1996 to 2011 was US$3.1 billion and US$0.42 billion for 2011 alone (Brookes and Barfoot, 2013, Forthcoming).

Biotech alfalfa

Herbicide tolerant RR®alfalfa was first approved for commercialization in the USA in 2005. The first pre-commercial plantings (20,000 hectares) were sown in the fall of 2005, followed by larger commercial plantings of 60,000 in 2006. The 60,000 hectares of RR®alfalfa represented approximately 5% of the 1.3 million hectares alfalfa seeded in 2006. Herbicide tolerance is expected to be the first of several traits to be incorporated into this important forage crop. A court injunction in 2007 suspended further plantings of RR®alfalfa until a new dossier of information was submitted to the regulators for consideration. Before the injunction came into force, another 22,000 hectares were planted bringing the total RR®alfalfa in the USA in 2007 to 102,000 hectares. There are approximately 9 million hectares of alfalfa grown for dry hay in the USA, annually worth US$7 billion. Unlike the large biotech row crops of soybean and maize, biotech alfalfa is likely to be more of a niche market. After several court hearings, RR®alfalfa was cleared for planting in early 2011, and it was estimated that US hectarage of RR®alfalfa in 2011 was up to ~200,000 hectares (APHIS, 2011). It is estimated that another 225,000 hectares were seeded in 2012 for an estimated total of 425,000 hectares.

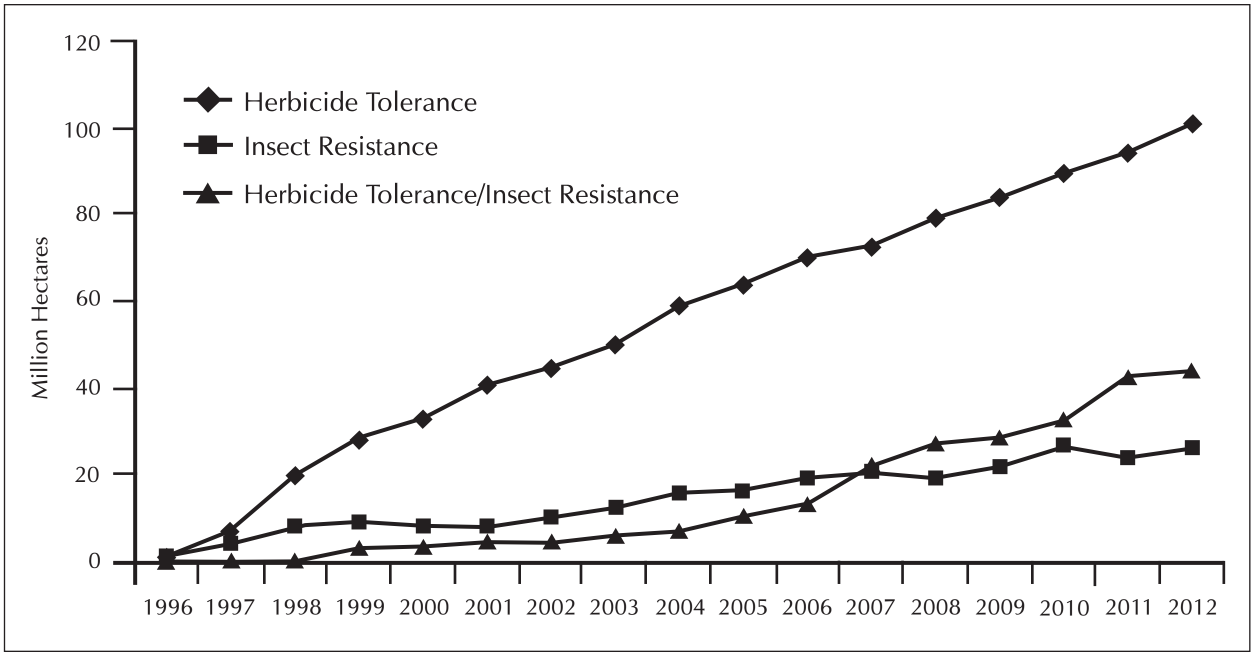
Other biotech crops

Small areas of biotech virus resistant squash (2,000 hectares) and PRSV resistant papaya in Hawaii (2,000 hectares with a 60% adoption) continued to be grown in the USA in 2012; the papaya industry in Hawaii was destroyed by PRSV and saved by the biotech papaya which is resistant to PRSV. In China in 2012, 6,275 hectares were planted to PRSV resistant papaya, an 18% increase over the 5,300 hectares in 2011, and ~500 hectares of Bt poplars.

Distribution of Biotech Crops, by Trait

During the 17 year period 1996 to 2012, herbicide tolerance has consistently been the dominant trait (Figure 36). In 2012, herbicide tolerance, deployed in soybean, maize, canola, cotton, sugarbeet and alfalfa occupied 100.5 million hectares or 59% of the 170.3 million hectares of biotech crops planted globally (Table 40); this compares with 93.9 million hectares equivalent to 59% of the total biotech hectarage in 2012. Thus, herbicide tolerance increased by 7% from 93.9 million hectares in 2011 to 100.5 million hectares in 2012. Stacked traits increased from 42.2 million hectares in 2011 to 43.7 million hectares – an increase of 1.5 million hectares equivalent to 4% increase from 2011. Hectarage featuring insect resistance also increased from 23.9 million by 9% to 26.1 million hectares in 2012. The large increases in all three traits were due largely to significant increases in

Figure 36. Global Area of Biotech Crops, 1996 to 2012: by Trait (Million Hectares)



Source: Clive James, 2012.

Table 40. Global Area of Biotech Crops, 2011 and 2012: by Trait (Million Hectares)

Trait	2011	%	2012	%	+/-	%
Herbicide tolerance	93.9	59	100.5	59	+6.6	7
Stacked traits	42.2	26	43.7	26	1.5	4
Insect resistance (Bt)	23.9	15	26.1	15	2.2	9
Virus resistance/Other	<1	<1	<1	<1	<1	--
Total	**160.0**	**100**	**170.3**	**100**	**10.3**	**6**

Source: Clive James, 2012.

soybean and maize hectarages in Brazil, but also in other countries that contributed strong growth in 2011 including Canada, South Africa and smaller countries like Paraguay. The stacked traits for herbicide tolerance and insect resistance are deployed in both cotton (Bt/HT) and maize (Bt/Bt/IR, Bt/HT, and Bt/Bt/HT) (Table 40). The Bt/Bt/IR stack refers to different Bt or other IR genes that code for different traits, for example above ground pests and below ground pests in maize. In terms of year-over-year increases, the highest growth was for the stacked at 31%, followed by herbicide tolerance at 5% with insect tolerance decreasing by -9%. The trend for increased use of stacks is expected to continue as country markets mature and more stocks are offered in the market. This stacking trend will continue and intensify as more traits become available to farmers. Stacking is a very important feature of the technology with SmartStax^{TM} comprising 8 genes coding for three traits, launched in the USA and Canada in 2010, and realizing continued growth in 2012.

The deployment of stacked traits of different Bt genes and herbicide tolerance is becoming increasingly important and is most prevalent in the USA which had approximately 70% of the 43.7 million hectares as "stacked traits" in 2012, this compares with 73% in 2011, so the percentage in the US will drop as stacks become relatively more prevalent in other countries. In 2012, the other seven principal countries, of a total of 13, which deployed stacked traits in 2012 were: Brazil (5.6 million hectares), Argentina (3.4 million hectares), Canada (1.3 million hectares), South Africa (1.2 million hectares), Australia (0.5 million hectares), Philippines (0.7 million hectares) and Mexico (0.2 million hectares). Uruguay, Chile, Honduras, Paraguay, and Colombia, planted less than 0.1 million hectares each. These countries will derive significant benefits from deploying stacked products because productivity constraints at the farmer level are related to multiple biotic stresses, and not to single biotic stress.

Entomologist Dr. Anthony M. Shelton from Cornell University shares his views on insect resistance trait through the Bt gene (AM Shelton, 2012, Personal communication).

> "The commercialization of plants expressing insecticidal crystal (Cry) proteins from *Bacillus thuringiensis* (Bt) for insect management has revolutionized agriculture and become a major tool for integrated pest management (IPM) programs (Shelton et al. 2002, Romeis et al. 2008). In 2011, Bt crops were grown on more than 66 million ha in 26 countries (James, 2011). Bt crops have provided economic benefits to growers and reduced the use of other insecticides (Shelton et al. 2002; Qaim et al. 2008; Kathage and Qaim 2012; Lu et al. 2012), suppressed pest populations on a regional basis (Carrière et al. 2003; Wu et al. 2008; Hutchinson et al. 2010), conserved natural enemies (Naranjo, 2009) and promoted biological control services in agricultural landscapes (Lu et al. 2012).
>
> While this revolution in insect management in field crops should be applauded, it is unfortunate that these benefits have largely not been realized for vegetables. Although

statistics for insecticide use worldwide are combined for vegetables and fruits (45% of total insecticide value), if vegetables were conservatively estimated to equal half of this total (22.5%), the insecticide use for vegetables would exceed that for corn (7.6%) plus cotton (14.1%) (Shelton, 2012).

Sweet corn has been the most successful Bt vegetable to date. Bt sweet corn was introduced into the North American market in 1998 by Novartis Seeds and was based on event Bt 11, which expresses Cry1Ab and had already been registered for field corn in 1996 (Such piggy-backing on an event registered for field corn substantially reduces registration costs for "minor crops" such as sweet corn). This product provided excellent control of the European corn borer (ECB) but lesser control of the corn earworm (CEW) which required supplemental foliar sprays under high CEW populations. As with Bt cotton and Bt field corn, there is a trend to using multiple Bt toxins in sweet corn to enhance performance across a range of species. Thus, trials conducted in Maryland and Minnesota under high CEW pressure indicated superior control, compared to Bt11, with sweet corn expressing both Cry1Ab endotoxin (Bt11 event) and the vegetative insecticidal protein VIP3A (MIR 162 event) (Burkness et al. 2010).

In 2010 and 2011, trials were conducted in New York, Minnesota, Maryland, Ohio and Georgia to test the efficacy of newly developed Bt sweet corn varieties (Seminis® Performance Series™) expressing Cry1Ab.150 and Cry2Ab2 proteins. Across all locations, Cry1A.105 + Cry2Ab2 plants produced 98% ears free from insect damage. In New York in 2010, this product provided ≥99% clean ears even under very high CEW pressure, without the use of any foliar sprays. This was in stark contrast to the non-Bt isoline that had only 18% clean ears even with 8 sprays of a commonly used pyrethroid insecticide. These new Bt varieties were commercialized in 2011.

The early varieties of Bt sweet corn, based on the Bt 11 event, were embraced by growers, but then got caught up in the anti-biotech fervor of the late 1990s and early 2000s. They have now regained much of their market share and the newer varieties, including the Seminis® Performance Series™, will lead to much larger adoption of Bt sweet corn. While the environmental, health and economic benefits of Bt sweet corn adoption are clear, misinformation can still challenge their adoption. It is noteworthy that in 2012, anti-biotech activists submitted a petition to Walmart, the world's largest food retailer, with 463,000 signatures urging them not to sell Bt sweet corn (Common Dreams, 2012). However, Walmart denied their request saying they had examined the issue and determined that the corn was safe."

Distribution of economic benefits at the farm level by trait, for the first sixteen years of commercialization of biotech crops 1996 to 2011 was as follows: all herbicide tolerant crops at US$40.8 billion and all insect resistant crops at US$57 billion, with the balance of US$0.4 billion for other minor biotech crops. For 2011 alone, the benefits were: all herbicide tolerant crops US$6 billion, and all insect resistant crops US$13.6 billion plus a balance of US$0.09 billion for the minor biotech crops for a total of ~US$19.7 billion (Brookes and Barfoot, 2013, Forthcoming).

Dominant Biotech Crops in 2012

Herbicide tolerant soybean continued to be the dominant biotech crop grown commercially in 11 countries in 2012; listed in order of hectarage, the 11 countries were: USA, Argentina, Brazil, Paraguay, Canada, Uruguay, Bolivia, South Africa, Mexico, Chile and Costa Rica. Globally, herbicide tolerant soybean occupied 80.7 million hectares, (up 5.3 million hectares, or 7% from 2011), and representing 47% of the global biotech crop area of 170.3 million hectares for all crops (Table 41).

The second most dominant biotech crop was maize with stacked traits, planted in 39.9 million hectares (up 2.6 million hectares from 2011) which occupied 23% of the global biotech area, and

Table 41. Dominant Biotech Crops in 2012 (Million Hectares)

Crop	2011	2012	Change 2011-2012	% Change	% Global
Herbicide tolerant Soybean	75.4	80.7	5.3	+7	47
Stacked traits Maize	37.3	39.9	2.6	+7	23
Bt Cotton	17.9	18.8	0.9	+5	11
Herbicide tolerant Canola	8.2	9.2	1.0	+12	5
Herbicide tolerant Maize	7.7	7.8	0.1	+1.3	5
Bt Maize	6.0	7.5	1.5	+25	4
Stacked traits Cotton	4.9	3.7	-1.2	-24	2
Herbicide tolerant Cotton	1.8	1.8	– –	– –	1
Herbicide tolerant Sugar beet	0.5	0.5	– –	– –	<1
Herbicide tolerant Alfalfa	0.2	0.4	0.2	+100	<1
Others	0.1	<0.1	– –	– –	<1
Total	**160.0**	**170.3**	**10.3**	**6**	**100**

Source: Compiled by ISAAA, 2012.

planted in ten countries: the USA, Brazil, Argentina, South Africa, Canada, the Philippines, Uruguay, Honduras, Chile and Paraguay. The stacked maize category includes three combinations of traits: a double stack with insect resistance (Bt) and herbicide tolerance (HT), Bt/HT; a double stack with two traits for insect resistance, Bt/Bt; and a triple stack with two types of insect resistance, plus herbicide tolerance, Bt/Bt/HT. Maize with stacked traits occupied a total of 39.9 million hectares in 2012 compared with 37.3 million hectares in 2011 and occupying 23% of global biotech crop hectarage.

The third most dominant crop was Bt cotton, which occupied 18.8 million hectares, equivalent to 11% of the global biotech area, up 0.9 million hectares, or 5% since 2011 and planted in thirteen countries, listed in order of descending hectarage: India, China, Pakistan, Myanmar, Burkina Faso, Brazil, USA, Argentina, Australia, Colombia, Sudan, Paraguay and Costa Rica.

The fourth most dominant crop was herbicide tolerant canola, occupying 9.2 million hectares, up from 8.2 million hectares in 2011; this increase is equivalent to 5% of global biotech crops, and planted in four countries, Canada, USA, Australia and Chile.

The fifth most dominant crop was herbicide tolerant maize occupying 7.8 million hectares, equivalent to 5% of global biotech crop area and planted in nine countries – the USA, Paraguay, Brazil, Canada, Argentina, South Africa, the Philippines, Honduras and Chile.

The sixth most dominant crop was Bt maize which occupied 7.5 million hectares, up 1.5 million hectares from 2011 with a growth of 25% and equivalent to 4% of global biotech area and was planted in 17 countries in descending order of hectarage – Brazil, South Africa, USA, Paraguay, Argentina, Uruguay, Spain, Canada, the Philippines, Portugal, Czech Republic, Cuba, Slovakia, Honduras, Chile, Egypt, and Romania.

The seventh most dominant crop was stacked cotton, occupying 3.7 million hectares, down 1.2 million hectares from 2011 and occupying 2% of global biotech area, and planted in eight countries – USA, Argentina, Australia, Brazil, Mexico, Paraguay, Colombia and South Africa.

The eighth most dominant trait was herbicide tolerant cotton occupying 1.8 million hectares, the same as last year, occupying 1% of all biotech crops globally and planted in eight countries – USA, Brazil, Argentina, Paraguay, Australia, Mexico, Colombia and South Africa.

The balance of other crops listed in Table 41 occupied less than 1% of global biotech crop area and include, in descending order of area: herbicide tolerant sugarbeet grown on 0.5 million hectares in the USA and Canada and herbicide tolerant alfalfa grown on 0.4 million hectares in the USA in 2012. China grows about 6,275 hectares of virus resistant papaya. The “Others” category, with a total of less than 1,000 hectares, includes virus resistant papaya and squash in the USA, Bt poplars, sweet pepper and tomato in China.

Global Adoption of Biotech Soybean, Maize, Cotton and Canola

Another way to provide a global perspective of the status of biotech crops is to characterize the global adoption rates as a percentage of the respective global areas of the four principal crops – soybean, cotton, maize and canola – in which biotechnology is utilized (Table 42 and Figure 37). The data indicate that in 2012, 81% (80.7 million hectares) of the 100 million hectares of soybean planted globally (FAO, 2009) were biotech. Of the 30 million hectares of global cotton, 81% or 24.3 million hectares were biotech in 2012 compared with 82% or 24.7 million hectares planted to biotech cotton in 2011. Of the 159 million hectares of global maize planted in 2012 (FAO, 2009), more than one-third (35%) or 55.1 million hectares were biotech maize. Finally, of the 31 million hectares of canola (FAO, 2009) grown globally in 2012, 30% were herbicide tolerant biotech canola, equivalent to 9.2 million hectares, compared with 8.2 million hectares or 26% in 2011. If the global areas (conventional plus biotech) of these four crops are aggregated, the total area is 320 million hectares, of which more than half, 53%, or 170.3 million hectares, were biotech in 2012 – up from 50% and 160 million hectares in 2011.

Whereas critics of biotech crops often contend that the current focus on biotech soybean, maize, cotton and canola reflects only the needs of large commercial farmers in the richer industrial countries, it is important to note that two-thirds of these 320 million hectares are in the developing countries, farmed mainly by millions of small, resource-poor farmers, where yields are lower, constraints are greater, and where the need for improved production of food, feed, and fiber crops is the greatest.

The Global Value of the Biotech Crop Market

Global value of the biotech seed market alone was US$14.8 billion in 2012

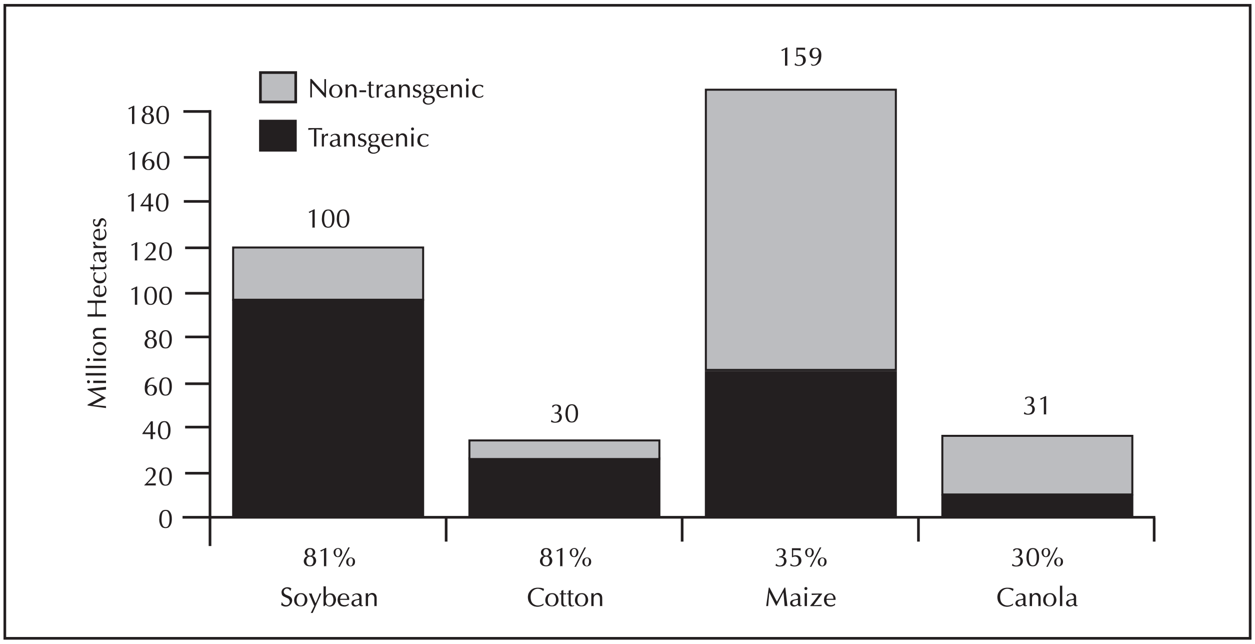
In 2012, the global market value of biotech crops, estimated by Cropnosis, is US$14.84 billion, (up from US$13.35 billion in 2011); this represents 23% of the US$ 64.62 billion global crop protection market in 2012, and 35% of the ~US$34 billion commercial seed market (Table 43 and Appendix 2). The US$14.84 billion biotech crop market comprised US$8.25 billion for biotech maize (equivalent to 56% of global biotech crop market, up from 53% in 2011), US$4.68 billion for biotech soybean (32%, down from 33% in 2011), US$1.26 billion for biotech cotton (9%), and US$0.4 billion for biotech canola (3%). Of the US$14.84 billion biotech crop market, US$11.4 billion (77%) was in the industrial countries and US$3.4 billion (23%) was in the developing countries. The market value

Table 42. Biotech Crop Area as Percent of Global Area of Principal Crops, 2012 (Million Hectares)

Crop	Global Area*	Biotech Crop Area	Biotech Area as % of Global Area
Soybean	100	80.7	81
Cotton	30	24.3	81
Maize	159	55.1	35
Canola	31	9.2	30
Others	- -	1.0	- -
Total	**320**	**170.3**	**53**

Source: Compiled by ISAAA, 2012. *Latest FAO 2009 hectarage

Figure 37. Global Adoption Rates (%) for Principal Biotech Crops, 2012 (Million Hectares)



FAO Global hectarages for 2009.
Source: Compiled by Clive James, 2012.

Table 43. The Global Value of the Biotech Crop Market, 1996 to 2012

Year	Value (Millions of US$)
1996	93
1997	591
1998	1,560
1999	2,354
2000	2,429
2001	2,928
2002	3,470
2003	4,046
2004	5,090
2005	5,714
2006	6,670
2007	7,773
2008	9,045
2009	10,607
2010	11,780
2011	13,251
2012	14,840
Total	**102,241**

Source: Cropnosis, 2012 (Personal Communication).

of the global biotech crop market is based on the sale price of biotech seed plus any technology fees that apply. The accumulated global value for the 17 year period, since biotech crops were first commercialized in 1996, is estimated at US$102,241 million.

A holistic estimate of the value of biotech crops globally and in the USA was recently documented by Carlson (2009) who noted that the annual ISAAA estimates (James, 2008) detailed above, are only “for seeds and licensing revenues rather than from ‘crops’, which have much greater market value.” He also indicated that “Worldwide farm-scale revenues from GM crops are difficult to assess directly, but that good data are available for the United States.” In 2008, the USDA Economic Research Service reports that 80-90% of all corn, soy, and cotton grown in the United States is biotech.

Published reports by Carlson (2009) enabled him to estimate revenues from the major GM crops at about US$65 billion in 2008 in the USA alone. Given that the USA has approximately 50% of global biotech crop plantings, Carlson estimated that "global farm-scale revenues from GM corn, soy and cotton in 2008 were about double the US gains of US$65 billion, equivalent to US$130 billion." For the US alone, taking into account the biotech crop revenue figure of US$65 billion plus contributions from GM drugs ('biologics') and GM industrial products (fuels, materials, enzymes), which Carlson had previously estimated (Carlson, 2007) – he estimated that US revenues alone in 2007 from all GM products (biotech crops, biologics and industrial products) was approximately US$240 billion and growing at 15-20% annually. Given the US GDP, of about US$14.3 trillion in 2008, Carlson estimated that revenues from all GM products in the USA could amount to the equivalent of about 2% of US GDP in 2009.

The estimated global farm-gate revenues for the harvested commercial "end products", (the biotech grain and other harvested products) is obviously many-fold greater than the value of the biotech seed alone (US$14.8 billion). Extrapolating from the 2008 data of Carlson, 2009, detailed above, the value of the biotech harvested grain from biotech seed would be worth ~US$170 billion globally in 2012, and projected to increase at up to 10-15% annually.

A 2011 Philips McDougal publication reported that the costs for discovery, development and authorization of a new plant biotechnology trait introduced between 2008 and 2012 was US$136 million. The survey also concluded that: the time from the initiation of a discovery project to commercial launch was on average 13.1 years; the time associated with registration and regulatory affairs is increasing from a mean of 3.7 years for an event introduced before 2002, to the 2011 estimate of 5.5 years; regulatory science, registration and regulatory affairs accounts for the longest phase in product development, estimated at 36.7 percent of total time involved; and the trend in the number of units (candidate genes, constructs or genetic events) being screened in order to develop one trait is increasing (McDougal, 2011).

Global Status of Regulatory Approvals

While 28 countries planted commercialized biotech crops in 2012, an additional 31 countries totalling 59 have granted regulatory approvals for biotech crops for import, food and feed use and for release into the environment since 1996. A total of 2,497 regulatory approvals involving 25 GM crops and 319 GM events have been issued by competent authorities in 59 countries, of which 1,129 are for food use (direct use or processing), 813 are for feed use (direct use or processing) and 555 are for planting or release into the environment. Of the 59 countries with regulatory approvals, USA has the most number of events approved (196), followed by Japan (182), Canada (131), Mexico (122), Australia (92), South Korea (86), New Zealand (81), European Union (67 including approvals that have expired or under renewal process), Philippines (64), Taiwan (52) and South Africa (49).

Maize has the most number of approved events (121 events in 23 countries), followed by cotton (48 events in 19 countries), potato (31 events in 10 countries), canola (30 events in 12 countries) and soybean (22 events in 24 countries). The event that has received the most number of regulatory approvals is the herbicide tolerant maize event NK603 (50 approvals in 22 countries + EU-27), followed by the herbicide tolerant soybean event GTS-40-3-2 (48 approvals in 24 countries + EU-27), insect resistant maize event MON810 (47 approvals in 22 countries + EU-27), insect resistant maize event Bt11 (43 approvals in 20 countries + EU-27), insect resistant cotton event MON531 (36 approvals in 17 countries + EU-27) and insect resistant cotton event MON1445 (31 approvals in 14 countries + EU-27).

A comprehensive inventory of biotech crop products that have received regulatory approvals for import for food, feed use and for release into the environment including planting in specific countries can be found at the ISAAA website (http://www.isaaa.org/gmapprovaldatabase/default.asp).

DROUGHT – THE MOST IMPORTANT CONSTRAINT TO CROP PRODUCTIVITY GLOBALLY – A HISTORICAL PERSPECTIVE

Global Droughts and their impact particularly in developing countries

Introduction

Drought is a global phenomenon that can occur in any environment, arid or humid, rich or poor, tropical or temperate in countries of the South and the North. It is often triggered by a combination of abnormally low rainfall, high temperatures, leading to the formation of metrological high pressure systems. Whereas much of severe weather, such as hurricanes, tornadoes, earthquakes and tsunamis, are all short-lived, droughts are usually the opposite – the worst droughts deteriorate gradually with time, are long-lived, can last up to several years, and often encroach stealthily on communities with an ultimate capacity to inflict grave devastation, and in the worst cases, famine and death. Whilst droughts in industrial countries can cause enormous problems, in developing countries, drought can deny people's access to food and water and threaten survival. Whilst industrial countries have the infrastructure and capacity to deal with emergencies associated with drought, poor developing countries do not have that capacity, and have to suffer life-threatening consequences. The following paragraphs provide a historical perspective of droughts in selected developing countries, with a particular focus on Africa, and the two most populous countries in the world, China and India, where the droughts of the past have been devastating. The impact of droughts in the USA, including 2012, is also briefly reviewed. The historical records on drought, particularly those dating back centuries, are understandably often anecdotal but nevertheless provide an important perspective of the general severity and impact of drought through the ages. The source of information on droughts dating back to 1900 and beyond, utilized in this review, is the OFDA/CRED International Disaster Database, Centre for Research on the Epidemiology of Disasters at the Catholic University in Louvain Belgium (EM-DAT, 2012).

This background information on drought serves as an introduction and a preamble to the special feature by Dr. Greg Edmeades on the status of drought tolerance in conventional and biotech maize, in the following chapter of this Brief. The review is timely in that it coincides, in 2012, with one of the worst droughts for fifty years in the USA, and also with the launch of the first biotech drought tolerant maize in the USA in 2013. More importantly, the same biotech maize technology to be used in the USA in 2013 has been donated by the private sector companies, Monsanto and BASF, to a public-private sector partnership called WEMA (Water Efficient Maize for Africa). This is a creative project designed to develop drought tolerant maize, both conventional and biotech, for use by small resource-poor farmers in Sub Sahara Africa, where it might hopefully be available as early as 2017.

Global Overview

The world map (Figure 38) provides a very general global snapshot of the countries which suffered major droughts, many of which led to famines, over the last 112 years, 1900 to 2011. The map is designed only to provide a very general global overview not a detailed analysis of the occurrence and frequency of droughts. Countries were arbitrarily assigned to three categories (High >12 droughts, Medium 6 to 12 droughts, and Low <6 droughts), based on the number of droughts experienced during the 112 year period 1990 to 2011. The countries which suffered the highest number of droughts (high >12) are shaded in black, medium (6-12 droughts) are shaded in charcoal, and low (< 6 droughts) are shaded in light grey.

High category (>12 droughts)

In Africa, the countries which suffered most droughts (>12 droughts) are clustered in the Horn of Africa including Ethiopia, Kenya and to the South Mozambique; in West Africa Mauritania and Niger were the worst. The countries that suffered the most in Asia were China and India, and Brazil in Latin America.

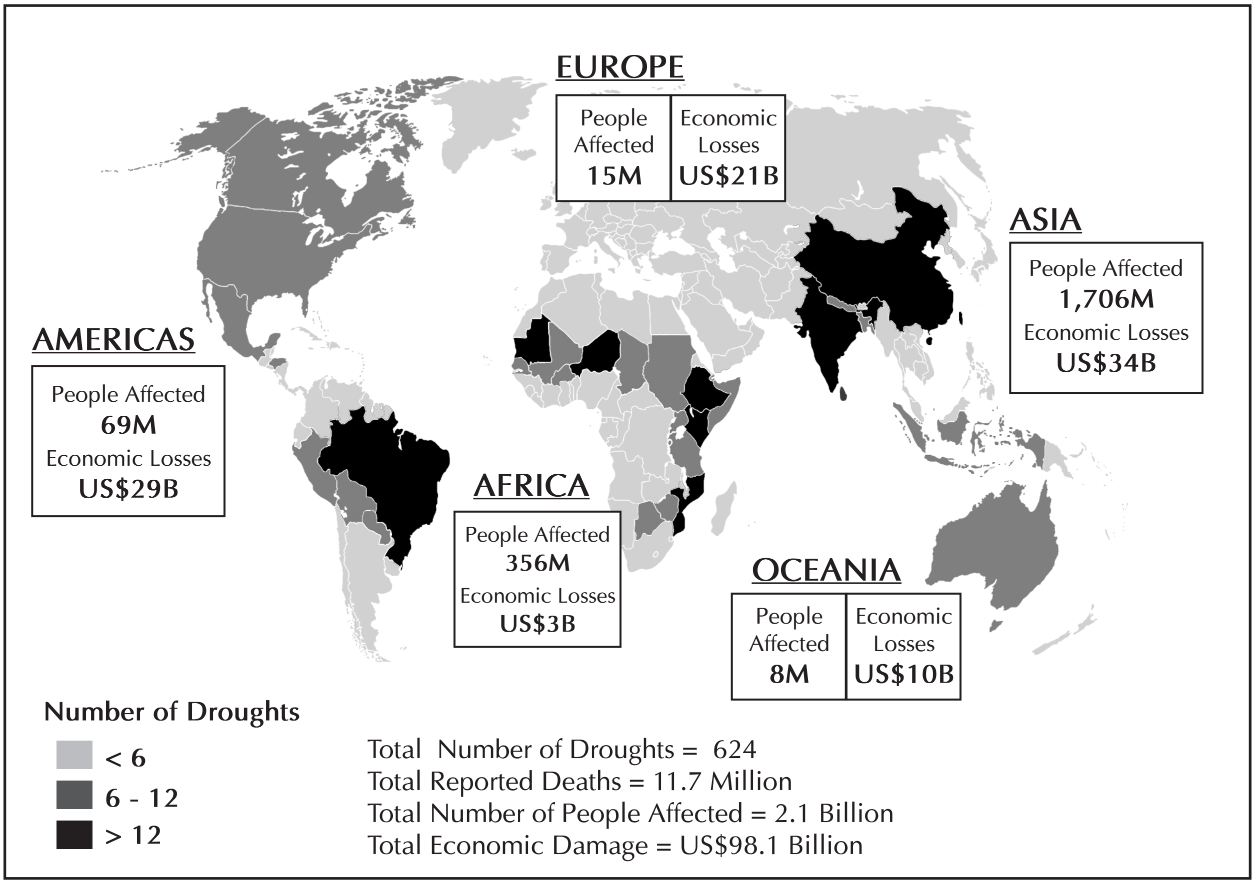
Medium category (6 to 12 droughts)

In Africa, the countries in the Sahel region that were affected by drought at the medium level (6 to 12 droughts) include Mali, Burkina Faso, Chad, Sudan Somalia, Tanzania, Zimbabwe and Botswana; the US, Canada and Mexico in North America; Peru, Bolivia and Paraguay in South America; Australia and several countries in Asia.

Low category (<6 droughts)

East and West European countries fall into this category plus the southern cone and northern

Figure 38. World Map of Severe Droughts by Country, People Affected, and Economic Losses by Continent, 1900 - 2011



Total Number of Droughts = 624
Total Reported Deaths = 11.7 Million
Total Number of People Affected = 2.1 Billion
Total Economic Damage = US$98.1 Billion

Source: Modified from EM-DAT, 2012; Compiled by ISAAA, 2012.

countries (Colombia and neighboring countries) of Latin America. Also included are most countries of Central and North Africa.

The map also provides a general overview of the number of people affected by droughts for the period 1900 to 2011 and the estimated losses in US dollars, by continent. The highest number of people affected by droughts during the period 1900 to 2011 were in Asia (1.7 billion), followed by Africa (356 million), the Americas (69 million), Europe (15 million) and Oceania 8 million. Asia was also the continent that suffered the highest economic loss (US$34 billion), followed by the Americas (US$29 Billion), Europe (US$21 billion), and Oceania (US$10 billion).

Data in Table 44 and Figure 39 indicate that of the 624 droughts recorded globally in the 112 year period, 1900 to 2011, almost half (46%) were in Africa (288 droughts), followed by Asia (152 or 24%), the Americas (127 or 21%), Europe (38 or 6%) and Oceania (20 or 3%). Twelve million people died as a result of the 624 droughts and they affected over 2 billion people globally during the 112 year period 1900 to 2011. Of the 12 million people who died, 9.7 million were in Asia, 844,000 in Africa and the balance of 1.2 million in the Soviet Union (included under Europe in Table 44).

Although Africa had more droughts (288) than Asia (151) during the period 1900 to 2011, the number of people who died from droughts was much greater in Asia (9.7 million) than Africa (0.8 million); one of the factors is the higher population in Asia compared with Africa: ~4 billion in Asia versus ~1 billion in Africa. Of the 2 billion people affected by droughts 79%, equivalent to 1.7 billion, were in Asia, 17% equivalent to 356 million were in Africa, 3% in the Americas and 1% each in Europe and Oceania (Figure 40).

Droughts in Africa

The annals of history indicate that drought has been one of the biggest killers in Africa since the beginning of agriculture 10,000 years ago, and it is still one of the biggest killers today. In the Horn of Africa the 1984-85 drought led to famine which killed 750,000 people. The severe drought in Eastern Africa in 2011 was the worst in 60 years which resulted in famine and the destroyed lives and livelihoods of 9.5 million people. The drought caused a food crisis in several countries including Somalia, Djibouti, Ethiopia, Uganda and Kenya. Drought is the major constraint to increased crop production globally, most particularly in Africa, where it has caused massive devastation and destruction. Maize is the staple diet for over 300 million poor people in Sub Saharan Africa where throughout the ages, droughts have not only robbed them of their food, but also robbed them of their dignity as human beings.

The data in Table 44 and Figure 38 shows that of the 624 disastrous droughts globally during the ~112 period, 1900 to 2011 approximately half (288 or 46%), were in Africa, followed by Asia at 24% and 21% for the Americas. The 288 droughts in Africa resulted to an estimated 844,143 deaths, and affected 356 million people with damage assessed at almost US$3 billion.

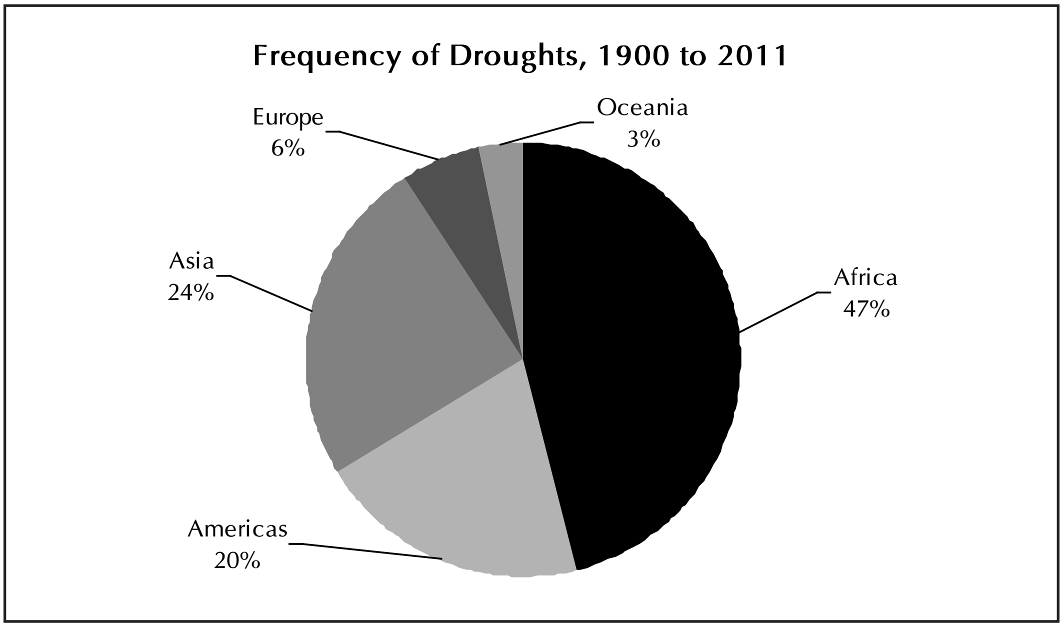
The data in Figure 41 shows the countries which suffered major droughts in the last 12 years, 2000 to 2011. The worst years were 2011 and 2006 when drought struck more than ten countries. The least number of droughts was experienced in 2005 and 2008. Whereas drought is widespread throughout Africa, the frequency of droughts in African countries seem to be generally higher in East Africa in countries like Ethiopia, Djibouti, Mozambique, Kenya, Uganda, Somalia, Tanzania, and Madagascar. In the Sahel region of West Africa the worst droughts seem to be in countries like Burkina Faso, Mauritania, Senegal, Mali, and Niger.

Table 44. Frequency and Impact of Droughts, by Continent, 1900 to 2011

Continent	Frequency of droughts	Total Reported Deaths	Total Number of People Affected (Millions)	Total Economic Damage (US$ Millions)
Africa	288	844,143	356	2,920
Asia	151	9,663,389	1,706	34,251
Americas	127	77	69	28,811
Europe	38	1,200,002*	15	21,461
Oceania	20	660	8	10,703
Total	**624**	**11,708,271**	**2,154**	**98,146**

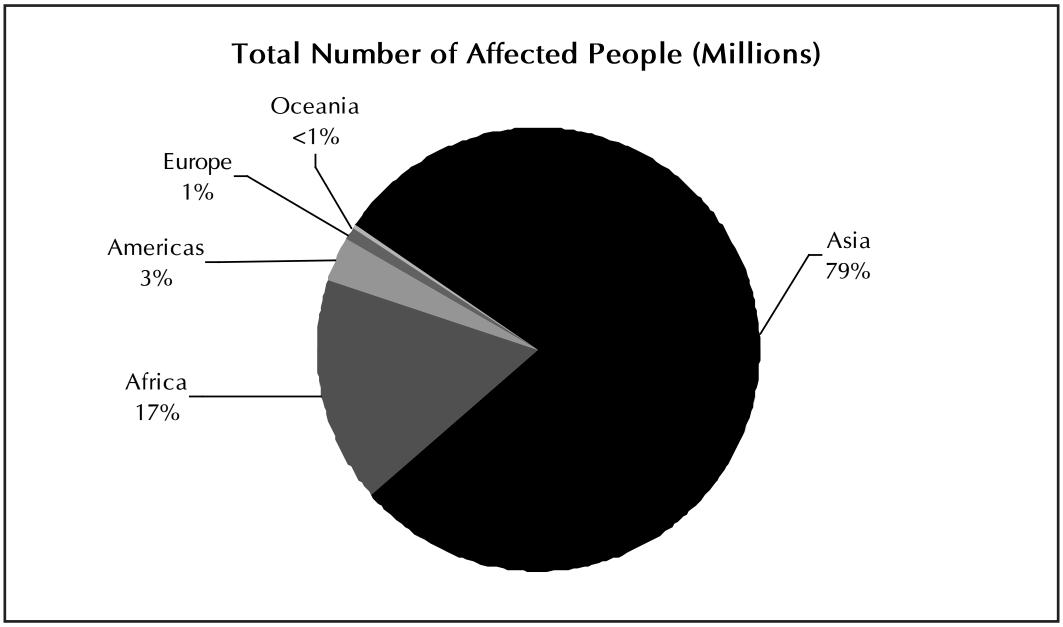
*The mortality data for drought listed in Europe is due to a drought/famine related event in the Soviet Union in 1921 which killed 1.2 million people.
Source: Compiled by ISAAA, 2012. *Latest FAO 2009 hectarage

Figure 39. Frequency of Droughts by Continent Expressed as % of Global Total, 1900 to 2011



Source: Modified from EM-DAT, 2012; Compiled by ISAAA, 2012.

Figure 40. Number of People Affected by Drought, by Continent Expressed as % of Global Total, 1900 to 2011



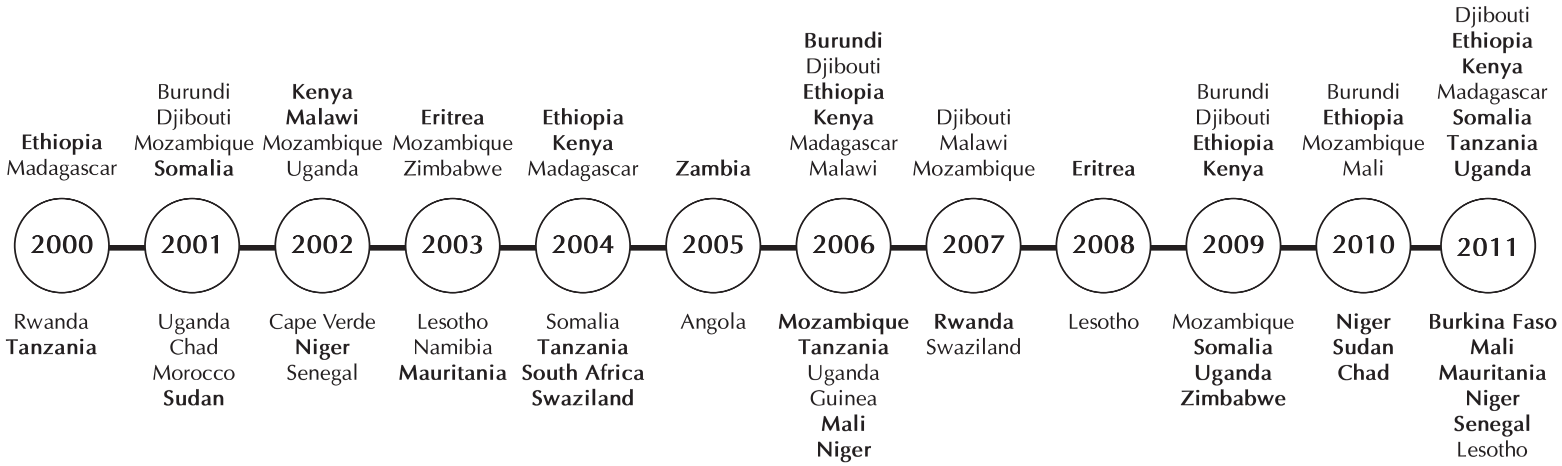
Source: Modified from EM-DAT, 2012; Compiled by ISAAA, 2012.

Almost 19 million people are currently suffering from hunger in the Sahel region of Africa, the dry land on the southern edge of the Sahara desert, including many countries such as Mali and its neighbors. The UN estimates that in the Sahel, 1 million children under the age of five are at risk of facing death, and another 3 million are "acutely malnourished." This is the third time in seven years (2005, 2008 and 2012) for the region to face hunger and **the current crisis was caused by the old enemy – drought** and high food prices leading to unaffordability of food. Programs to build "resilience" against drought are being put in place to try and counter inadequate policies to ensure food security in the region. In June 2012, the countries in the Sahel region requested US$1.6 billion from donors to urgently help address imminent hunger and malnutrition (The Economist, 7 July 2012).

Droughts in Asia

The legendary and seasonal monsoon rains of Asia provide water for crops that feed half of humanity. When they do not arrive on time, or in insufficient quantity, they can cause momentous droughts that result in hunger, famine and death for millions. A new tree ring study identified at least four epic droughts that have impacted on Asia in the last 1,000 years (Science Daily, 24 July 2010).

Figure 41. Major Droughts in African Countries, 2000 to 2011



Source: Modified from EM-DAT, 2012; Compiled by ISAAA, 2012.

- The first drought in 1644 probably led to the collapse of the famous Ming dynasty in China.
- The second in 1756-68 coincided with the fall of the kingdoms of territories of today's Vietnam, Myanmar and Thailand.
- The third, the East India drought of 1790 to 1796, had broad implications worldwide.
- The fourth, was the Great Drought of 1876 which killed up to 50 million people in countries ranging from China to India

The data in Figure 39 shows that Asia had the second highest number of droughts (151) after Africa (288) in the 112 period 1900 to 2011. However, because of the higher population of Asia, compared to Africa, the number of deaths attributed to drought were much higher in Asia (9.7 million) compared with Africa at 800,000 deaths.

Droughts in China:

In China, agriculture is practiced in very diverse climatic and production conditions. Crop productivity in China depends heavily on the monsoon that delivers wet summers. China has 109 million hectares of arable land equivalent to 12% of the 932 million hectares of its total land mass. Failure in the monsoon has significant impact on crop productivity particularly in the low rainfall areas (<330mm) in the North-East and South-West regions of this vast country. Inadequate precipitation not only affects productivity on the 109 million hectares of arable land in China that produces 480 million tons of food grains, but also severely impacts on 400 million hectares of pasture lands, for the growing Chinese livestock industry. Observers have noted that China has experienced over 1,000 major droughts since 200 BC (Wu et. al., 2011) with a trend of more droughts since 1950. A recent report on drought in China concluded that there were 17 severe droughts since 1950 (ABARES, 2012). Typically, China suffers from drought once every two years in some part of the country. The most intense drought of 1644 probably led to the collapse of the famous Ming dynasty in China. In the nineteenth century, the most severe and spatially widespread drought in the last 300 years occurred in North China; this resulted in the Northern Chinese Famine of 1876 to 1879 during the Qing dynasty that killed an estimated 10 million people in different provinces of Northern China (Zhixin, 2008). The twentieth century witnessed the most frequent and disastrous droughts in the history of China. The NOAA reported that numerous droughts related disasters have occurred in China in the twentieth century; the most notable were the Chinese Famine of 1907, North China Famine of 1928-30, New China Famine of 1936, Chinese Famine of 1942-43, the Great Chinese Famine of 1956 to 1961 and the Eastern China Famine of 1965-66 (NOAA, 1999).

Some observers claim that the Great Chinese Famine of 1956 to 61, which killed at least 10 million people, was one of the greatest tragedies in the history of China (Bristow, 2012; Esterhuyse, 2012). During this period, grain production plummeted to its lowest point in history. The droughts continued after the Great Chinese Famine of 1956-61. The severe droughts of 1964-65, 1978, 2000 and 2006 are important reminders of the severity and intensity of droughts in rural China. Wu et al. 2011 noted that the drought situation has deteriorated in China since the 1990s and is now occurring almost every year and causing more and more grain losses, even threatening the security of drinking water supplies. It is estimated that up to 30% of the total crop area of China is prone to drought, and therefore combating drought by all means including the development and deployment of drought tolerant biotech crops is a high priority for China.

Droughts in India

India is extremely vulnerable to droughts that can affect almost three-quarters of the country's land area. Two-thirds of the total cultivated land of 140 million hectares is rainfed. India depends primarily on the South-West summer monsoon that have become increasingly erratic, unpredictable and delayed. Generally, India receives an annual average rainfall of 1160 mm in summer, known as *Kharif* season (DAC, 2012). Notably, 73% of annual rainfall comes in only 100 to 120 days from June to September during the South-West Monsoon. However, the frequent abnormality in the temporal and spatial rainfall, which provides 75-90% of the annual rainfall during summer, causes drought-situations in the low rainfall areas of the country (Parthasarathy, 2011). The Department of Agriculture estimated that over 68% of the total 140 million hectares of cultivated land is drought prone to varying degrees; this exposes millions of people to a drought crisis (DAC, 2012). Around one-third of the total land area that receives less than 750mm of rainfall is classified as "chronically drought prone area" while 35% receives rainfall of 750mm to 1125mm – this is classified as the "drought-prone area". Historically, drought-induced famines have caused a great loss of human lives and they include the following:

- The Bengal Famine of 1769-70;
- The Great Famine of 1876-78 in Southern India;
- Indian Famine of 1896-97 in Western India;
- The Bengal Famine of 1943-44 estimated to have taken the lives of tens of millions of people in the country (Kumar, 1983).

In the last 65 years, India has not been subject to the severe droughts experienced in the distant past. In recent times, the worst droughts have been in the state of Bihar in 1966-67; the Maharashtra drought of 1972-73 and the West Bengal drought of 1979-80. Severe droughts occur once every 8 to 9 years in arid and semi-arid zones in the country. In these regions, catastrophic droughts are rare occurring on average, once every 32 years. However milder local droughts can occur almost every third year and they tend to affect pockets of land in the affected areas (Sinha, 1999). In recent times, the droughts of 1987 and 2002 were the worst with a rainfall deficiency of 19%, affecting 47% of the land area, and impacting a population of 100 million people.

Oceania, South East Asia, and Latin America

Drought can affect all countries in Asia and Oceania at some time or other. More recently, Australia suffered a multi-year drought, starting in 2008. Vietnam suffered a severe drought causing famine in 1945 and North Korea in 1996. Of the three continents of the South, Latin America is the least affected by droughts, with 127 droughts in the 112 year period 1900 to 2011, compared with 288 for Africa and 151 for Asia. Brazil, which covers approximately half the land mass of South America, has historically suffered very severe droughts as well as several severe droughts in recent times, Droughts have generally been more sporadic and less severe in other countries of South America.

Droughts in the USA

The worst droughts in the history of the United States of America was during the Dust Bowl of the 1930s, the very dry 1950s, the 1980s and this year, 2012 – which produced the worst drought in the USA in over fifty years. Climate change and global warming are predicted to increase drought frequency and severity due to increased evaporation. Droughts are periodic, and ironically often alternate with floods and are certain to continue in the future. A brief overview of the droughts in the US in the last 100 years will serve to remind us that droughts have been frequent and devastating and will continue to be so in the future.

1930s - The Dust Bowl

The Dust Bowl of the 1930s lasted from 1930 to about 1936. Often called the Dirty Thirties, it was the most severe drought in the US in the last 100 years. It caused severe ecological and agricultural damage on an estimated 50 million hectares of land. The Dust Bowl was caused by a severe and long drought, coupled with extensive deep ploughing of the virgin soil of the Great Plains. Ploughing of the fragile topsoil was exacerbated by little or no rotation of cover crops and the tenets of good farming practices to control soil erosion and to conserve moisture were not respected. The Dust Bowl caused most damage in the panhandles of Texas and Oklahoma and the neighboring states of New Mexico, Colorado and Kansas. Millions of farmers migrated from the Dust Bowl area to try and seek out a living and survive in less affected states like California. The Pulitzer Prize author, John Steinbeck, wrote about the life changing experiences of the drought migrants in *The Grapes of Wrath* and *Of Mice and Men* (in wikipedia.org/wiki/Drought in the United States).

The Dry 1950s

From 1950 to 1956 lack of rain and high temperatures affected the Great Plains and the Southwest, causing a long lasting and severe drought. Between 1949 and 1951 rainfall decreased in Texas by 40% and in some places drought-related crop losses were as high as 40%. By the end of the drought 244 of Texas’ 254 counties were declared Federal Disaster areas.

The Droughts of the 1980s

Starting in 1980 to 1983, drought affected the Corn Belt and the Mid West where it caused great grief to farmers with damage estimated at US$24 billion. A devastating widespread drought in 1988 affected more than a third of the United States, mainly in the Great Plains, where damage was estimated at its highest since the Dust Bowl of the 1930s at US$39 billion. National losses from the U.S. drought of 1988 exceeded US$40 billion, more than the losses caused by Hurricane Andrew in 1992, and the San Francisco earthquake of 1989.

The Drought of 2012

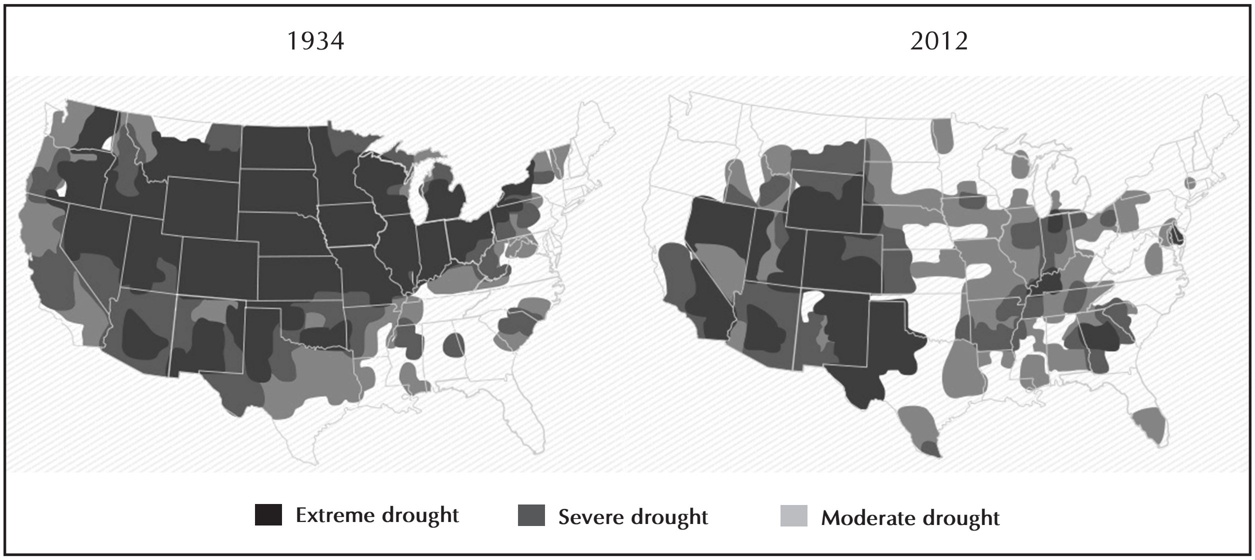
The 2012 drought in the US was estimated to have affected 26 of the 52 states, and cover at least 55% of the land area of the USA, which is almost 1 billion hectares. In comparison, the more severe Dust Bowl drought of 1934 covered almost 80% of the US land area. Drought maps for 1934 and 2012 (Figure 42) compare the extent of extreme, severe and moderate droughts (Rice and Raasch, 2012).

The other three significant droughts in the last twenty five years in the USA were in 1980, 1988 and 2011. The estimated cost of the droughts (in 2012 adjusted dollars) were as follows (Figure 43):

In the US, by the end of July 2012, drought and extreme heat had affected more than 1,000 counties in 29 states and they were designated natural disaster counties by USDA. As of July 2012, compared with the average year, 38% of the US maize crop had already been rated as poor and similarly 30% of soybean was rated poor. Given that the maize crop is the most important in the US valued at US$76.5 billion in 2011, final estimates of losses for 2012 are expected to be substantial. The drought in Texas alone in 2011 was estimated to have cost US$7.6 billion and final losses for 2012 are likely to be much higher. Since US maize and US soybean exports represent 53% and 43% of global maize and soybean exports, respectively, the impact of the 2012 drought on international prices are likely to be significant (The Economist, 21 July 2012). There is some comfort in the fact that global rice and wheat supplies were relatively plentiful in 2012 and the hope is that they will preclude a broad escalation of commodity prices as was the case in 2008. Maize is more vulnerable than soybean to price escalation because the shortfall in maize production could be exacerbated by the demand for maize for biofuel production in the US (The Economist, 21 July 2012).

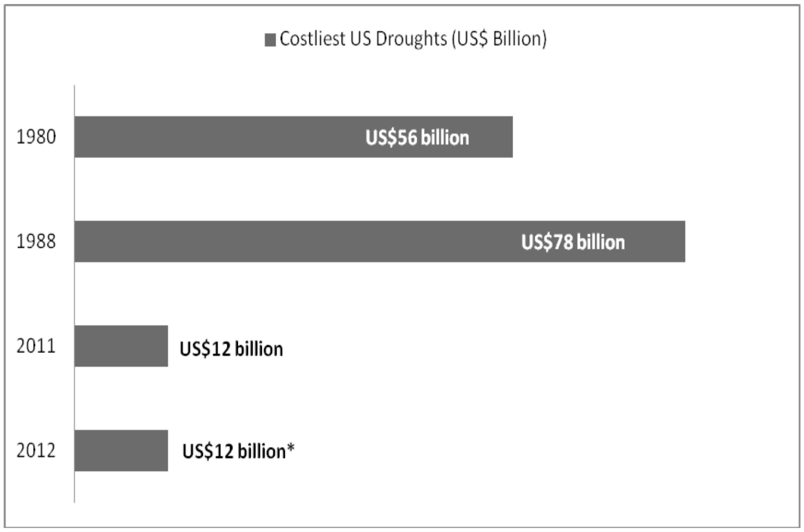
Some preliminary estimates in July 2012 suggested that losses in the US soybean and maize area affected by drought could be as high as 30% (Rice and Raasch, 2012) but reliable estimates will not be available until later. Preliminary estimates by USDA suggested that the 2012 drought would result in increases in food prices of 3 to 4% in 2013, with beef prices increasing by 4 to 5%.

Figure 42. Comparing Droughts, 1934 and 2012



Source: Rice and Raasch, 2012

Figure 43. Costliest US Droughts



Source: National Climatic Data Center cited by Pompa USA Today article of 25 July 2012
*Initial estimate to be updated later

Special feature on Drought Tolerance in Maize

The proverb ***"Water is the staff of life"*** reminds us that water is important and precious. Agriculture currently uses over 70% (86% in developing countries) of the fresh water in the world. Water tables are dropping fast in countries like China, and water supplies will continue to shrink worldwide as global population will grow from the current 7 billion to more than 9 billion people in 2050. Whereas people drink only 1 to 2 liters a day, the food and meat we eat in a typical day requires 2,000 to 3,000 liters to produce. Both conventional and biotechnology approaches are instruments to develop crops that use water more efficiently and are more tolerant to drought. Given the lack of water and its cardinal role in crop production, it follows that tolerance to drought and efficient water usage should be assigned the highest priority in developing future crops. The situation will be further exacerbated as global warming takes its toll, with weather expected to become generally drier and warmer, and as competition for water intensifies between people and crops.

Drought tolerance conferred through biotech crops is viewed as the most important trait that will be commercialized in the second decade of commercialization, 2006 to 2015, and beyond, because it is by far the single most important constraint to increased productivity for crops worldwide. Drought tolerant biotech/transgenic maize, is the most advanced, and the first biotech maize will be launched commercially in the USA in 2013. Notably, a private/public sector partnership (WEMA) hopes to release the first biotech drought tolerant maize as early as 2017 in sub-Saharan Africa where the need for drought tolerance is greatest.

Given the pivotal importance of drought tolerance, ISAAA invited Dr. Greg O. Edmeades, former leader of the maize drought program at the International Maize and Wheat Improvement Center (CIMMYT), to contribute a timely global overview on the status of drought tolerance in maize, in both conventional and biotech approaches, in the private and public sector, and to discuss future prospects in the near, mid and long term. The contribution by Dr. Edmeades, ***"Progress in Achieving and Delivering Drought Tolerance in Maize -- An Update"***, supported by key references, is included as the following chapter in Brief 44 as a special feature to highlight the enormous global importance of the drought tolerance trait, which virtually no crop or farmer in the world can afford to be without. Of all the water on earth, only 0.003% is available for human consumption hence using water at current rates when the world will have to support 9 billion people or more in 2050, is simply not sustainable. The review on drought tolerant maize is particularly relevant to sub-Saharan Africa, because of the urgent humanitarian need to boost the yields of maize, which is the staple food for more than 300 million people, a significant proportion of whom are suffering from hunger and malnutrition.

Progress in Achieving and Delivering Drought Tolerance in Maize -- an Update

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ABSTRACT

Drought in 2012 through much of US Midwest has led to reductions of 15% and 21% in national maize production and maize yields, respectively, and cast a sharp focus on progress towards drought tolerance in this important crop. Drought also continues to destabilize maize yield in major regions of sub-Saharan Africa where irrigation is not feasible, with a direct human cost. Maize yield under drought mainly reflects tolerance to water stress of the kernel setting mechanism at flowering.

Genetic improvement can probably close 20-25% of the yield gaps between droughted and optimal conditions. Conventional selection by CIMMYT specifically for drought tolerance and focused on yield and associated secondary traits has resulted in gains of around 100 kg/ha/yr in tropical maize populations. Selection by the private sector in temperate germplasm, based on multilocation trials for general performance has given gains under drought of ~65 kg/ha/yr. Heat tolerance is becoming more important as climate changes, and the genetic controls of heat and drought tolerance are largely independent of each other. Representative managed stress environments have been endorsed as an important component of efficient selection for drought or heat tolerance. Marker-assisted selection (MAS) is now having a significant impact, and when well executed could double gains from conventional drought tolerance selection. Current seed company claims, based on 2012 US data, appear to show Syngenta's Agrisure Artesian™ and Pioneer's AQUAmax™ hybrid products, selected using native genes and MAS, outyielding competing hybrids by around 500 kg/ha, while Monsanto's Droughtgard™ transgenic hybrids outyielded AQUAmax hybrids by a further 300 kg/ha. The Droughtgard event, MON87460 will be available to farmers royalty-free under the WEMA Project in five countries in sub-Saharan Africa, hopefully from 2015 onwards. Product delivery of drought tolerant hybrids remains a challenge in sub-Saharan Africa, but private seed sector capacity is increasing rapidly. Large publicly funded projects are now supplying drought tolerant inbreds and hybrids to national and regional seed companies in sub-Saharan Africa and South Asia. Public-private partnerships, though still rare, are using cutting edge doubled haploid, MAS and transgenic technologies to develop drought tolerant hybrids and deliver them successfully to smallholders in sub-Saharan Africa.

Experience since 2008 has reduced expected gains under drought in a commercial maize breeding context, with the exception of MAS. Starting with a base yield of 3 t/ha under drought, conventional breeding for regional adaptation should reliably deliver 50 kg/ha/yr (~1.4%/yr). MAS, which has performed well in the recent past, can boost these by a further 25 kg/ha/yr (~0.6%/yr) with potential for significantly larger gains from newer methodologies. The slower than expected development of transgenic drought tolerance suggests gains of 30 kg/ha/yr (0.7%/yr), assuming one new transgene is available every eight year that lifts yield 5% per transgene. Over the next two decades gains of 1.4, 2.0 and 2.7% per year can be expected from conventional selection, conventional + MAS, and conventional + MAS + transgenes, respectively. Greater gains are probable if genomic selection attains its potential and drought transgenes can be efficiently stacked. Impacts could be realized much sooner if harmonized biosafety and hybrid release policies were adopted. Germplasm collections are assuming greater importance if gains from native genes are to be sustained. Efficient and accurate field phenotyping remains essential for genetic progress. In sub-Saharan Africa trained and well-supported field staff are urgently needed. Emerging private-public partnerships in crop development and a strong private seed sector will be more than adequate to meet these challenges as long as our resolve does not falter and we use our resources efficiently.

Introduction

Drought has major implications for global food supply because of the expected effects of gradual climate change over the next century, and the variation in climatic extremes in the short term that it is expected to bring. Although increased temperature is a more predictable outcome than changes in rainfall patterns accompanying climate change, it is generally considered that major maize producing areas will become warmer, drier and subject to an evolving array of maize diseases and pests that are new to those areas.

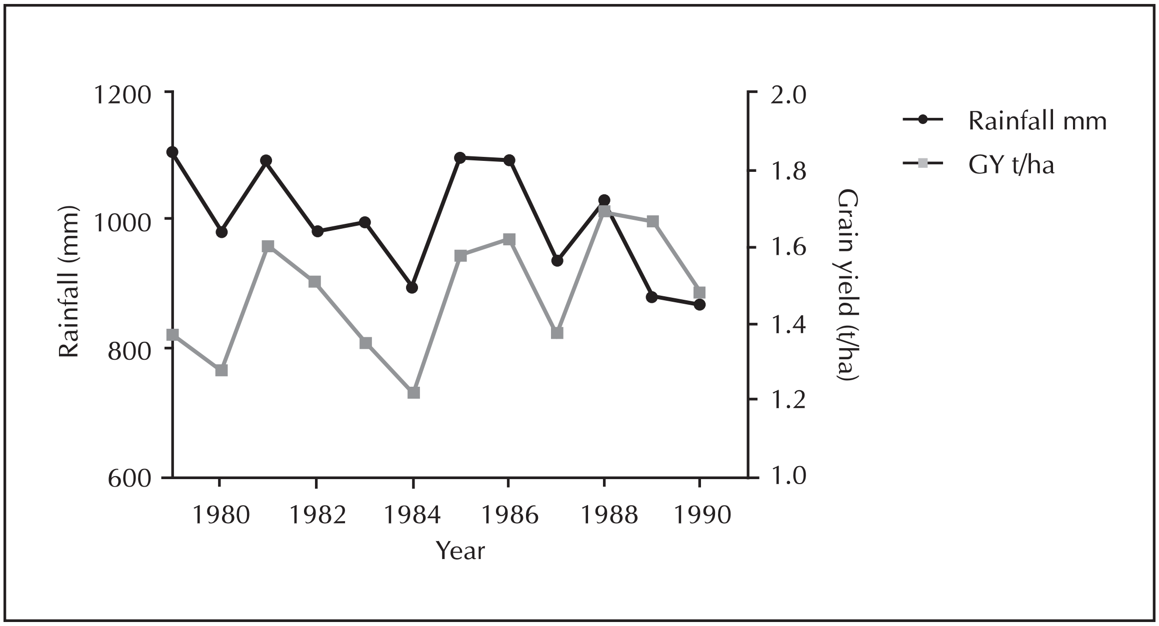
These trends were apparent four years ago when an earlier review of progress in drought tolerance in maize was published (Edmeades, 2008), but their relevance has been brought sharply into focus by the severe drought encountered in the central and south of the US Corn Belt during 2012, with effects being felt as far north as Canada. The United States normally produces 38% of the world's maize (FAOSTAT, 2012), so the reductions of 21% and 15% in US maize yields and production in 2012, compared with 2009-11 mean levels, has implications globally (http://quickstats.nass.usda.gov/). The EU-27 countries produce around 12% of global maize, and their yields in 2012 have also been reduced by an average of 12.5% by heat and drought (MARS, 2012). With this in mind, it was decided to review again the status of drought tolerant maize germplasm and its supply. This review will follow the same general outline of Edmeades (2008), summarizing the key points from that review and updating with new information as appropriate.

1. Drought and maize: the scope of the problem

Maize is the cereal with the largest annual global production at 829 M tons annually (vs. 690 M t/yr for rice and 675 M t/yr for wheat). Maize grain yields in the temperate developed world of North America and Europe average 8.7 ton/ha vs. 3.7 t/ha in less developed tropical countries of Asia and Africa (FAOSTAT, 2012). In both production environments drought is the most important abiotic stress constraining and destabilizing maize grain production. Its effects are particularly severe in southern and eastern Africa where most maize is rainfed. For example, in the period 1990-2009 mean yield of South Africa had a coefficient of variation (CV) of 23% vs. 7% for the US on mean yields of 4.1 and 9.8 t/ha (FAOSTAT, 2012).

Most of the 160 m ha of maize grown globally is rainfed. The proportion of the crop area irrigated in the US is around 14%, in China 40% and in Egypt close to 100%, but in most other countries it is often less than 10%. Losses of yield to drought annually are thought to average around 15% of well-watered yield potential on a global basis, a figure that equates to 120 M tons of grain. At today's prices this is worth around $36 billion, but the real costs are in terms of human welfare in sub-Saharan Africa where maize is a staple food for more than 300 million people. Drought often afflicts whole regions, such as eastern and southern Africa (Figure 1), or the Sahel and the

Figure 1. **Maize grain yield in selected East and Southern African countries is directly affected by rainfall recorded in maize growing areas during the season (unpublished data, CIMMYT).**



Sudan savannas of West Africa in 2011, creating regional food shortages that cannot easily be alleviated by cross-border trade. The production of maize in southern Africa fluctuated from 12.5 million tons in 1992 (a drought year) to 23.5 m tons in 1993 (Bänziger and Araus, 2007). In 2011, a year of moderate food relief activity, the World Food Program purchased 410,000 tons of maize worth more than $100 M today for sub-Saharan Africa (WFP, 2012). Drought-tolerant maize could still play a significant part in meeting the Millennium Development Goal of "halving by 2015 the share of people suffering from extreme poverty and hunger."

Regional and national yields only tell part of the story. In fields with varying topography, texture and thickness of topsoil, yields may vary ten-fold. The normal practice of sowing a single variety or hybrid in such a field implies the need for a good level of drought tolerance to reduce this level of within-field yield variation.

The prospects of adding additional irrigated land on which maize will be grown are relatively slight, given that irrigated land area is projected to increase at a rate roughly equal to or less than the population growth rate. As well, there is a steady decline in many of the water tables in key food producing areas such as the North China Plain, the Indo-Gangetic Plain and in the High Plain states fed by the Ogallala aquifer in the US. A recent study suggests that the greatest water shortages will be encountered in the basins of the Niger, Ganges and Yellow Rivers that feed

11.6% of global population, and India's food supply is at risk because it uses 25% of all water used in agriculture globally (Knight et al. 2012).

Trends due to climate change and reduced soil quality all suggest an increased need for drought tolerance – but increasingly linked to heat tolerance as well. A recent study by Lobell et al. (2011) noted that about 65% of the maize growing areas of Africa would experience yield losses if there was a 1°C increase in mean temperatures under well-watered conditions. They estimated that this would rise to 100% of any area that was under drought. Improvements in drought and heat tolerance would presumably offset this trend. A 1°C rise in average temperature is also estimated to increase the intensity of the global water cycle by 8% due to increased evaporation rates (Knight et al. 2012).

The yield gap between well-watered crop potential yield and water-limited yield is often large, but as a rough rule of thumb 20-25% of this gap could be eliminated by genetic improvement in drought tolerance, and a further 20-25% by application of water-conserving agronomic practices. The remaining 50-60% can only be met by irrigation – when available and affordable (Edmeades et al. 2006). This review focuses on the genetic improvement of drought tolerance and to a lesser extent heat tolerance. However, equally important will be the improvement and use of water saving agronomy such as drip irrigation and conservation tillage, as well as reductions in losses through leaks in major irrigation structures.

2. How maize responds to drought and heat stress

Typical visual symptoms of drought stress in maize are a change in colour from green to green-grey, and rolling of the lower leaves followed by those in the upper canopy. At the same time stomates are closing, photosynthesis is being sharply reduced and growth is slowing. When stress coincides with the 7-10 day period prior to flowering, ear growth will slow more than tassel growth and there is a delay in silk emergence relative to pollen shed, giving rise to an interval between anther extrusion and silk exposure. This anthesis-silking interval (ASI) can be used to predict drought-induced yield reduction. At the same time leaf senescence begins at the base of the plant and spreads upwards to the ear. Severe stress at flowering may lead to the complete abortion of ears and the plant becomes barren. Drought-affected ears typically have fewer kernels that will be poorly filled if drought extends throughout grain filling (Edmeades et al. 2000).

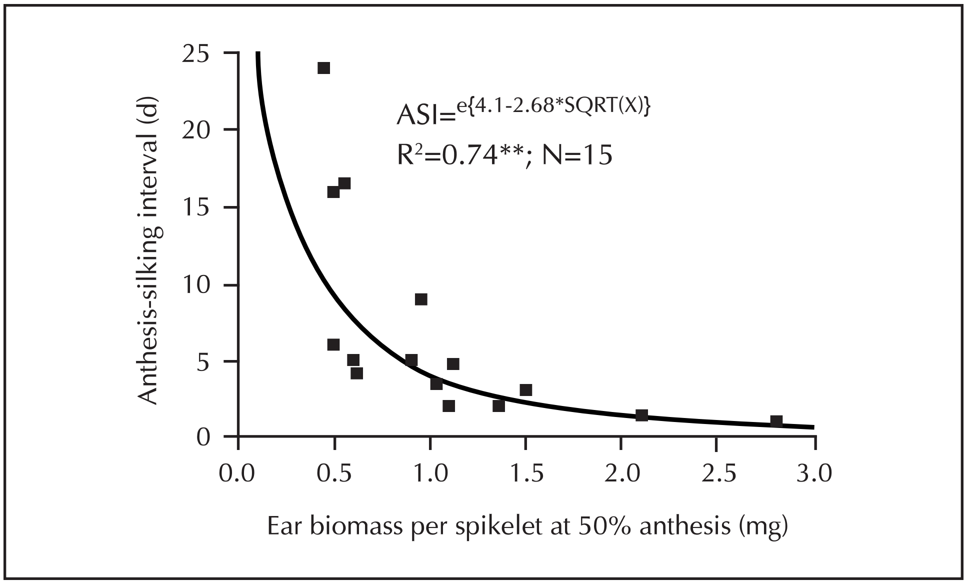
Genetic and management strategies that target improved grain yields in a water-limited environment target three variables (Passioura, 1977). These are the amount of water captured by the plant (W), the efficiency with which that water is converted to biomass (water use efficiency, WUE), and the harvest index (HI) or the proportion of biomass forming grain. Each of these variables can be altered. Osmotic adjustment of roots of temperate maize can increase the amount of water taken up from a drying soil (Chimenti et al. 2006), but increasing root depth through genetic control of morphology is likely to be a more effective means of increasing W. Development of a deeper rooting habit is effective when there are no physical barriers to root growth, and the wetting front from rain or irrigation extends downwards beyond the rooting zone. Research suggests that deeper roots are needed rather than an increase in root biomass, and variation for root depth occurs among genotypes (Edmeades et al. 2006). Apart from the obvious step of irrigation, other growing practices can alter W substantially. Good weed control and the managed variation in plant density are practices that control the amount of water available for transpiration.

WUE is maximized by early planting of crops, and by maintaining healthy leaves with high levels of nutrients (Passioura and Angus, 2010). Extending "staygreen" through selection for delayed leaf senescence is generally considered important for maintaining WUE and root health, and also for increasing the duration of kernel filling -- though the relationship between staygreen scores and grain yield under drought is often weak (Chapman and Edmeades, 1999). Blum (2009) noted that selecting only for WUE however may reduce yields and argues that effective use of water (EUW) implying maximum water capture and conversion to grain should be the goal. From a practical breeding perspective the two approaches (WUE and HI vs. EUW) are similar.

The numbers of kernels set and filled under drought stress accounts for most of the variation in maize grain yield under drought (e.g., Bolaños and Edmeades, 1996; Edmeades et al. 2000; Barker et al. 2005), and directly affects HI. Kernel number is largely determined at flowering. The slower growth of ears under drought sometimes means that pollen is shed before silks emerge, and in very uniform hybrids with small tassels pollination may fail because of pollen shortage. Generally however, the slow growth of the ear prior to silking is reflected in slow growth and small size of ovules, weak silk growth and a failure to set grain even when pollinated with adequate amounts of fresh pollen. In extreme cases no silks may emerge from the husk, and the plant becomes barren.

Events at flowering play a critically important part in yield stability (or lack of it) under drought. Partitioning of assimilate to the developing ear directly affects ovule growth at flowering and the ASI (Figure 2). Modern crop improvement has increased assimilate flow to the developing ear so kernel set is stabilized and grain yield is increased, and ASI is one trait that is extensively used for this purpose. In highly selected temperate maize, improvement in yield has been attributed largely to increases in stress tolerance, in part through this mechanism (Duvick et al. 2004; Tollenaar and Lee, 2011). However, there is also evidence that ASI has been improved in modern hybrids to a level where its correlation with grain yield is declining, and that selection for traits

Figure 2. **Relationship between ear biomass per plant at 50% anthesis and the anthesis silking interval observed in the same plots (modified from Edmeades et al., 1993).**



such as synchronous silk emergence on the ear may drive further increases in kernel set under drought (Schussler et al. 2011; Araus et al. 2012).

Kernel set must be followed by kernel filling to ensure that yield potential is realized. Kernels near the tip of the ear will often abort after several weeks of growth if drought-affected. Remobilized assimilate stored in the stem prior to and during the flowering period normally plays a role in buffering filling rate only in the last half of filling. Maintaining an active green leaf area plays a role in reducing effects of drought during grain filling on kernel final weight. A component of this is resistance to photo-oxidation of chlorophyll (or bleaching when there is an imbalance of excitation pressure – see Hüner et al. 2012) by bright sunshine striking a leaf that has lost its turgor and its capacity to photosynthesize at normal rates.

Heat tolerance is becoming increasingly important. High temperatures are often, but not always, associated with drought since transpiration which cools the crop is sharply reduced as leaves begin to roll. The effects of temperature on growth and development are well known – warmer temperatures increase development rate more than photosynthetic rate, so less assimilate is available per growth stage, resulting in reduced yields. Yields decline, but crops will mature more rapidly. Replacing existing hybrids with selections that are later maturing will partially offset this trend.

A more serious issue arises when high temperature spikes coincide with the susceptible growth stages in maize of flowering and early grain fill, and farmers can do little to alleviate this stress. Adaptation to heat stress is defined by Cairns et al. (2012) as tolerance to “temperatures above a threshold level that results in irreversible damage to crop growth and development.” They note that this threshold is lower for reproductive organs than for vegetative structures. Pollen viability in Corn Belt germplasm was reduced when severed tassels were held at 38°C (Schoper et al. 1987), but the degree of damage varied by hybrid. Female tissues are thought to be more tolerant to heat in maize. However, Edreira et al. (2011) reported increased pollination failure and a large increase in kernel abortion when ears were heated and held at 33-40°C. High temperatures also reduce leaf area and accelerate leaf senescence (Cairns et al. 2012) but there are clear and heritable differences among inbred lines in tolerance to temperatures exceeding 40°C in the field (Chen et al. 2012). Root elongation in maize seedlings is also reduced by high temperatures (Trachsel et al. 2010), though differences in the temperature response of the rate of elongation of roots and leaves are much greater among species than within (Parent and Tardieu, 2012). There is increasing evidence that tolerances to drought and heat are under independent genetic control, and can be treated as two distinct traits (Cairns, pers. comm., 2012).

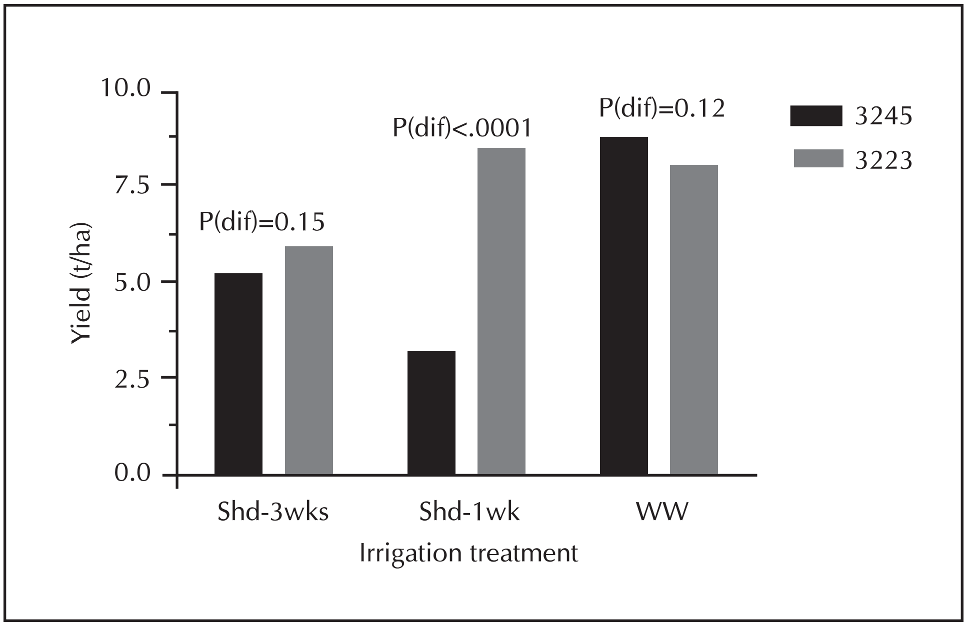
Our understanding of key genetic controls of root morphology, functional staygreen, and of key processes affected by high temperatures is relatively incomplete. It is generally agreed that drought tolerance from a breeding viewpoint is a complex trait that shows a high level of genotype x environment (G x E) interaction (Cooper at el. 2006) – though from the physiological viewpoint it can be simplified into several clear processes (Blum, 2011). Heat tolerance appears to be less complex, but there is little published evidence to date confirming this assertion.

3. Development of drought tolerant hybrids

a. *Requirements for successful development of drought-tolerant products*

Identifiable and heritable genetic variation for tolerance to drought or heat within a breeding population is first basic requirement for genetic progress in stress tolerance. Abraham Blum, a stress breeder of immense experience, suggested that stress tolerant alleles are present at low frequencies in most elite breeding populations, so these populations should be evaluated first (Blum, 1988). Evidence for useful genetic variation in elite breeding pools is found in significant levels of G x stress level interaction in response to drought stress (Figure 3). Arnel Hallauer, another widely respected breeder, frequently noted that the most important choice for a breeder was the breeding population chosen for improvement (Hallauer and Miranda, 1988). Unimproved sources such as landraces, while sometimes possessing unique alleles, are low yielding and are often poorly adapted and therefore difficult to evaluate.

Figure 3. Hybrid x water stress interactions on a sandy soil in Hawaii in two elite temperate maize single cross hybrids with similar flowering dates. On this very light soil water was withdrawn for only two weeks starting 3 wk or 1 wk before 50% anthesis, and compared with a well-watered (WW) control (after Bruce et al. 2002).



What traits are important? The most useful genetic variation is for the primary traits, grain yield under stress and unstressed conditions. However, variation for secondary traits such as yield components, especially kernel number per plant, and for the physiological components that contribute to the formation of yield under drought stress can speed progress for yield and allow the breeder to address key weaknesses in selections.

Ultimately, however, the justification for measuring secondary traits must always be their contribution to improved grain yield under stressed and unstressed conditions. There have been many secondary drought-tolerance traits proposed, but ease of measurement does not justify their use. Useful traits are those that are correlated with yield under stress, cheap and fast to measure, highly heritable, stable in expression and not associated with yield loss under unstressed conditions (Barker et al. 2005). Relatively few meet these criteria. For maize those associated with grain yield under stress, in descending order of importance have been kernel number (barrenness; kernel number per ear), a short ASI; increased leaf erectness; reduced canopy temperature; and increased visual staygreen and kernel weight (Bolaños and Edmeades, 1996). Where multiple traits are measured per genotype as well as grain yield, most breeders combine these data into a selection index or breeding value that heavily weights grain yield under stress and also includes unstressed yield to avoid loss of yield potential. Targeting of truly important traits during phenotyping, however, is still a work in progress (Passioura, 2012).

A second basic requirement for successful product development is access to a selection environment that lies within the target population of environments (TPE), but where stress intensity, timing and frequency can be reliably managed to expose genetic variation for traits season after season (Barker et al. 2005). Traditionally selection for stable yield has been through multilocation yield trials within the TPE, but drought in most maize TPEs is a randomly occurring event that gives rise to genotype x year interactions that are hard to interpret. Most drought breeders now prefer the "hotspot" approach, using managed drought stress environments (MSEs) -- rain-free testing sites that manage the timing and intensity of water stress though irrigation. The genetic correlation for grain yield between the MSE and the TPE should be positive and significant – something that should be tested as often as practicable. Increased interplant and interplot variability normally occurs under stress, and heritability of grain yield declines, so emphases on secondary traits and precision phenotyping are needed (Barker et al. 2005). Best practice calls for the standard use of statistical methods to remove spatial trends in data, but there is no substitute for careful selection and management of experimental sites. Well-irrigated control plantings are normally used to monitor changes in yield potential.

The need for high quality and high throughput phenotyping is increasing. Marker-aided selection (MAS) has helped reduce the volume of field testing, but the genotype-phenotype associations upon which MAS is based depend heavily on accurate phenotyping. This is especially the case when phenotyping training populations during genomic selection and when validating new genes and constructs. Nonetheless, the widespread use and rapid analysis of remotely sensed environmental and phenotypic data is allowing a steady increase in the volume of plots that can be evaluated for an array of current and new traits in real time (e.g., Araus et al. 2012; Berger et al. 2010; Masuka et al. 2012; Römer et al. 2012). New methods for the rapid evaluation of roots are emerging (Hund et al. 2010; Trachsel et al. 2011), and networks of managed stress testing sites at carefully chosen locations in the TPE are being established (Rebetzke et al. 2012). Phenotyping is catching up, but its precision, repeatability and speed still remain the bottleneck for the majority of genome wide association studies.

Models are becoming increasingly used as breeding aids. The combination of environmental and genetic data and crop and genetic models is now allowing the testing of genetic and physiological hypotheses *in silico* before a seed is planted (Chapman, 2008). Pioneer has developed advanced modeling capability of this type to support the development of drought tolerant products, for example AQUAmax (Messina et al. 2011), but still relies heavily on field testing as the final arbiter.

b. *Product development in the public sector*

Method development and validation: For the past 38 years CIMMYT has undertaken selection for drought tolerance in tropical maize using rain-free tropical locations and irrigation to create its MSEs. These studies have been extensively described elsewhere (Bolaños and Edmeades, 1996; Edmeades et al. 2000; 2006; 2008; Bänziger et al. 2006; Monneveux et al. 2006). In summary, recurrent selection using an index of traits was conducted for 2-9 cycles in six improved tropical populations, normally evaluated under well-watered and two distinct drought stress regimes in Mexico. Evaluations in multilocation trials under optimal, water stress (70% yield reduction) and low N environments (31% yield reduction) showed consistent gains averaging 164 and 99 kg/ha/cycle under drought and optimal conditions. Barrenness and ASI were also reduced under drought (Table 1). Gains in drought tolerance from selection under MSEs were significantly greater than those from selection in similar populations under multilocation testing alone. Gains transferred well to other environments such as moderately low N (Table 1; Bänziger et al. 1999), and showed only moderate levels of G x E. This suggests that selection resulted in a constitutive change in floral behaviour and reproductive efficiency through changes in biomass partitioning to

Table 1. Selection gains in six tropical maize populations. Four were evaluated at 3-6 water stressed (SS) sites, at 5-8 well-watered (WW) sites, or at two low N sites in 1992-4, and two (DTP1, DTP2) were evaluated at one low N, SS or WW location in 2002-3. Yields relative to unstressed levels were 30% under drought stress (SS) and 59% under low N.

Population	Cycles selected	Yield			ASI	Ears plant^{-1}
		SS	WW	Low N	SS	SS
			kg ha^{-1} cyc^{-1}		d cyc^{-1}	no. cyc^{-1}
La Posta Sequia	3	229**	53 ns	233**	-1.2**	0.07**
Pool 26 Sequia	3	288**	177**	207**	-1.5**	0.08**
Tuxpeño Sequia	8	80**	38**	86**	-0.4**	0.02**
Pool 18 Sequia	2	146**	126**	190**	-2.1**	0.05**
DTP1	6	160*	80 ns	210*	-0.6**	0.03**
DTP2	9	80*	120 ns	60 ns	-0.3**	0.01*
Mean Gain		**164**	**99**	**164**	**-1.0**	**0.04**

Symbols *, **, ns signify significant rate of change per selection cycle at $P<0.01$, $P< 0.05$ or $P>0.05$. (Edmeades, 2008; Monneveux et al. 2006).

and within the ear (Edmeades, 2008). Importantly, it became clear that improvements in performance under drought stress carried no penalty for yield under optimum conditions, and there was no evidence of negative correlations between the two.

Molecular breeding for improved drought tolerance in tropical germplasm began in the early 1990s at CIMMYT and has been strongly supported by the Generation Challenge Program. Initially it focused on identifying QTLs for key traits in progeny of biparental crosses, but the cross-specificity of QTLs and the absence of QTLs with large effects have rendered this approach of limited use. Proof of concept research showed that marker-assisted backcrossing of QTL from a tolerant donor to susceptible line improved performance under stress (Ribaut and Ragot, 2007) but the procedure with the marker technology available at the time was not cost effective. However, a maize consensus linkage map of key traits under drought, based on 40 evaluations of progenies from six tropical maize crosses, has been established (Ribaut et al. 2008), but shows large QTL x population interactions. Other meta-analyses of QTL have also identified consensus QTL for drought tolerance as well (e.g., Hao et al. 2010; Almeida et al. 2012). However, as noted by Bernardo (2008), the identification of distinct QTL has had little impact on public sector improvement for drought tolerance in maize. Furthermore, the detailed marker-assisted backcrossing needed to transfer the QTL is resource intensive and error-prone. Newer MAS breeding methods such as genomic selection minimize both of these issues.

Sub-Saharan African public sector programs: Based on the promising field results shown in Table 1, the locus of selection was moved to southern Africa in 1997 where the work was supported by a range of donors. Selection methods were modified to always screen under low N, drought stress at flowering and optimal conditions, and were applied in a regular pedigree maize breeding program, as described by Bänziger and Araus (2007). Emphasis was placed on grain yield and secondary traits whose heritability remained high under stress. National research programs also provided MSEs that were used to validate genetic gains obtained from testing in CIMMYT's key selection centers in Zimbabwe and Kenya. Initially there were large yield gains. CIMMYT-selected hybrids, when compared with current commercial hybrids from southern Africa across 36-65 sites, showed a 13-20% yield advantage in the 1-5 ton/ha yield range and a 3-6% in the 5-10 t/ha yield range (Bänziger et al. 2006).

The success of this approach led quickly to increased donor support. The Drought Tolerant Maize for Africa (DTMA) and the Water Efficient Maize for Africa (WEMA) Projects resulted --- both funded by the Bill and Melinda Gates Foundation for a 10 year period. The DTMA, initiated in 2007, involves CIMMYT, IITA and 13 national programs in sub-Saharan Africa. It uses conventional selection and MAS to improve germplasm adapted to the drier sub-

Saharan maize environments. Phenotyping is concentrated in well-developed regional MSEs established in Kenya, Zimbabwe, Zambia and Nigeria. DTMA has focused around conventional pedigree hybrid breeding as well as biparental marker-assisted recurrent selection (MARS) schemes. The WEMA Project started in 2009, involves CIMMYT, Monsanto and five eastern and southern African countries, and has a conventional, MARS, and transgenic components. Drought is also an issue in Asia: currently there are two drought tolerance projects underway in South East Asia, both led by CIMMYT and funded by the GCP or the Syngenta Foundation, and involving India, China, Vietnam, Indonesia, Thailand and Philippines.

Molecular breeding is an integral part of DTMA and WEMA. DTMA has a well-characterized association mapping panel of 293 diverse inbreds that have been used to identify genomic regions and sources of tolerance to drought and heat alone or in combination that could potentially be used in a wide range of germplasm (Cairns et al. 2013). The authors noted that some drought tolerant source lines became susceptible as temperatures increased, pointing to the need to screen for tolerance to both stresses simultaneously. It is noteworthy that 7 of the top 10 source lines in this study have come from populations selected solely for drought tolerance in Mexico – an indication of the role for source populations in which the frequency of stress tolerant alleles has been deliberately increased by targeted selection.

The MARS improvement schemes of DTMA and WEMA involve establishing marker-trait associations in the first cycle of phenotyping and using markers for the identified QTL to direct MAS in the following three cycles without further phenotyping. Large-effect QTLs accounting for more than 10% of the phenotypic variance have not been identified for drought tolerance in maize. MARS has therefore been modified to a form of genomic selection (GS) based on genome estimated breeding values (GEBVs). Recently CIMMYT has begun using up to 350,000 SNP markers based on genotyping by sequencing of 100 lines from each cross, and using these as training populations to impute the GEBVs of the remaining 100-150 families in each cross and to guide recombinations for the next three cycles. However, already DTMA and WEMA have created a unique database comprising 5000 lines from 27 inter-related populations that provides an excellent basis for genetic studies on drought tolerance in tropical germplasm, and will facilitate a flow of improved drought tolerant hybrids for several years to come.

Preliminary but incomplete estimates in sub-Saharan Africa of yield gains from conventional selection without markers reveal improvements of 39-80 kg/ha (or 1%) per year under optimal conditions, but only non-significant gains of 18 kg/ha (or 0.6-1.0%) per year under drought stress. Formal estimates of gain from the conventional breeding program and of MARS are currently underway. It is however apparent that gain under drought has been slowed by low heritability in regional trials and in trials under managed stress, often associated with soil variability, variable stands and managed levels of stress that are probably too severe. The need to select for disease resistance and broad adaptation has slowed progress for drought tolerance *per se*, yet is essential since these projects are producing finished products rather than drought tolerant sources. One key finding that will improve future testing efficiencies is a lack of significant G x E interaction for grain yield between eastern and southern African test sites. The ability to merge test site data across this region will result in improved heritability and genetic gain (Windhausen et al. 2012a).

Role of GWAS: There is broad general confidence among leading public sector maize researchers that the combination of doubled haploid (DH) inbred lines (see below) and genome-wide association systems (GWAS, essentially association mapping coupled with genomic selection) linked to precision field-based phenotyping, can double the current rate of genetic gain for yield and for drought tolerance as well. These techniques will undoubtedly be used much more extensively in the future since outsourced, rapid and cheap genotyping is now available, and high throughout phenotyping has made considerable progress (Bernardo, 2008; Lorenz et al. 2011; Yan et al. 2011). It is clear that the research community is learning how to use this technique since some authors have reported excellent predictive power from genomic selection (e.g., Crossa et al. 2010; Schussler et al. 2011) though others have reported far less success (Windhausen et al. 2012b). It is not surprising that the predictive power of a training population used to impute the GEBVs of other lines is greatest when the training population and lines are from similar genetic backgrounds, there is no hidden population structure among the lines, and when the training population and the predicted offspring are grown in similar environments (Windhausen et al. 2012b).

Heat tolerance: This has become a significant research area for CIMMYT maize scientists who have identified several excellent field screening sites (DTMA, 2012). Studies of grain yield under drought and/or heat stress show a non-significant relationship between them (Table 2), indicating that they can be improved independently. CIMMYT has recently

Table 2. Genotypic correlations among grain yields of a common set of topcrosses (Tester CML539 on 293 lines from the DTMA association mapping panel) assessed under drought (8 locations), drought with heat (3 locations), heat alone (1 location) and a well-watered control (6 locations) (Cairns et al. 2013).

	Drought	Drought + Heat	Heat
Drought + heat	0.08		
Heat	0.49	-0.07	
Well-watered	0.63	0.24	0.27

announced a partnership with USAID, Purdue University, Pioneer Hi-Bred and several South Asia partners to develop and deploy heat tolerant high yielding hybrids for South Asia where an estimated 15% of hybrid maize area is vulnerable to high temperatures (https://www.agronomy.org/science-policy/sspr/2012-11-07/#2012).

Transgenics in the public sector: Public sector efforts in delivering drought tolerance via transgenes in the absence of private sector partners are rare and at an exploratory level only. This is in part because of the costs involved in development and deregulation, and in part because of concerns about the complex nature of the trait.

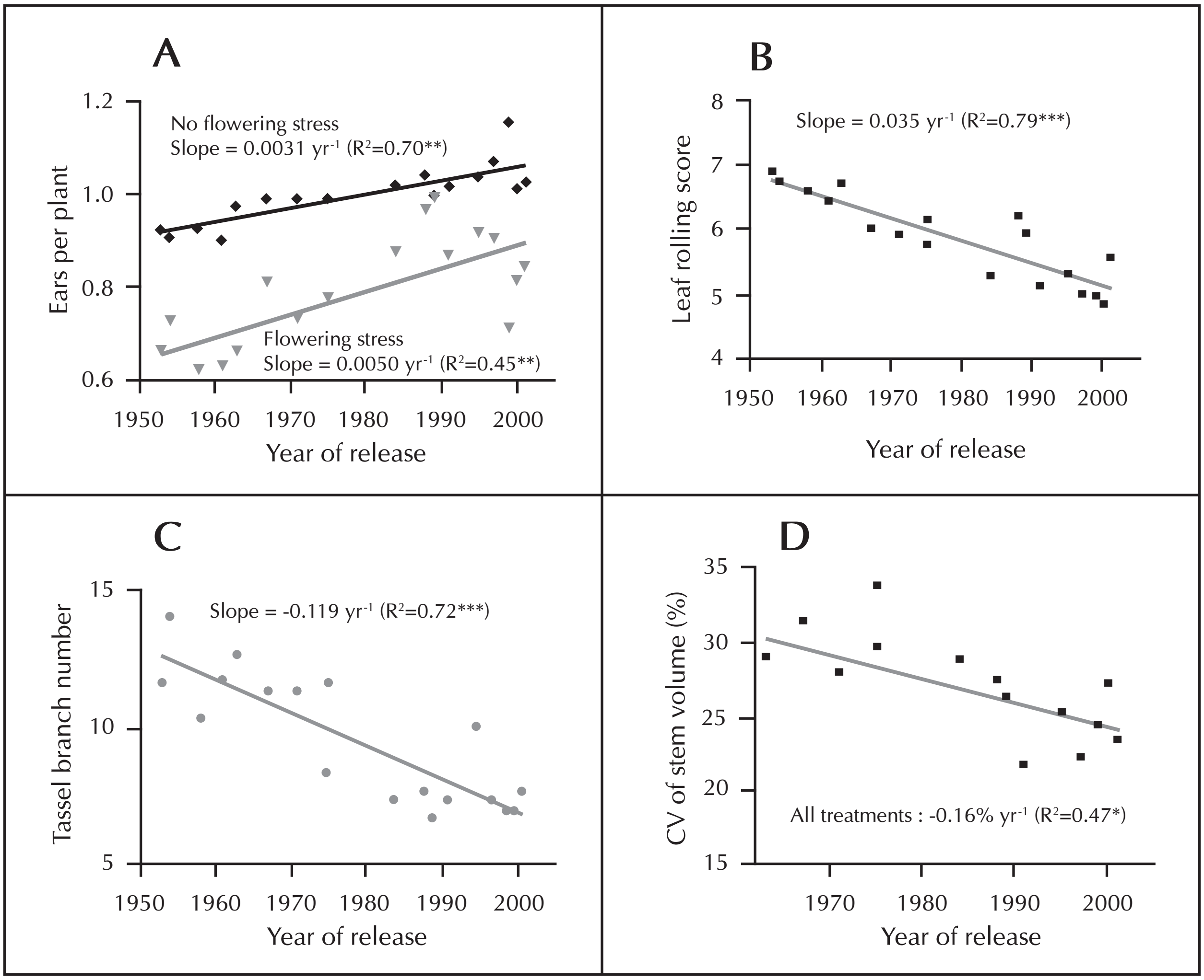
The role of the public sector: Although public sector breeding for drought tolerance has contributed meaningfully to the development of methodology and the supply of improved source germplasm, when compared with the multinational maize seed companies it generally lacks the sustained resources, the critical mass of staff, and sometimes the discipline and coordinated action to develop a consistent pipeline of drought tolerant products over decades. Exceptions are the flow of improved drought tolerant hybrids developed in DTMA and through public-private partnerships such as WEMA, but their success will depend on continuity of funding and staffing, and strong links to the private seed sector.

c. Product development in the private sector

Conventional: There has been significant improvement in drought tolerance in temperate commercial hybrids adapted to the US Corn Belt. The evidence for this is drawn mainly from hybrids developed by Pioneer, but older evidence points to a similar trend with DeKalb hybrids (Castleberry et al. 1984) and applies to most competitive temperate hybrids grown today.

We draw on results from a study of 18 elite commercial hybrids released in a time series from the mid 1950s through 2001 -- a subset of the full set of ERA hybrids studied extensively by the late Don Duvick (Duvick et al. 2004). All were developed through multi-location testing. Evaluations of changes in drought tolerance with time are described elsewhere in (Barker et al. 2005; Campos et al. 2006; Edmeades, 2008). Briefly these were evaluated in Chile over two seasons and subjected to drought stress at different growth stages from flowering to physiological maturity. This reduced grain yields by 36-71% compared to the irrigated control. Rates of gain in grain yield were greatest under unstressed conditions (196 kg/ha/yr), moderate under flowering stress (120 kg/ha/yr), and least (52 kg/ha/yr) in late-grainfill stress. Yield gains were accompanied by a decrease in ASI, an increase in kernels per plant, due mainly to reduced barrenness (Figure 4A) and less to increased kernels per fertile ear. As noted before (Edmeades, 2008), gains in weight per kernel and staygreen

Figure 4. **Gains from selection in a time series of temperate hybrids grown under drought stress imposed at different growth stages; A: Ears per plant; B: Leaf rolling score where 4 is rolled and 8 is flat; C: Tassel branch number; D: The coefficient of variation (CV) of stem volume per plant (Edmeades, 2006; unpublished data).**



were significant gain under irrigation but not under terminal stress, suggesting that in this circumstance kernels failed to fill fully under drought because of lack of current assimilate. Other changes, shown in Figsures 4B-4D, show that newer releases rolled their leaves more readily, had much smaller tassels and greater plant-to-plant uniformity.

In a similar study of the full set of 54 ERA hybrids under drought at two densities in Woodland, CA, Barker et al. (2005) reported similar trends. In this study, stress was imposed only at flowering and throughout grainfilling and was less severe than in Chile. Gains under irrigated conditions were around 50% those observed in Chile. Time to 50% silk was unchanged by year of release.

It is clear that progress in tolerance to drought at flowering has been made through selection based on extensive multi-environment trials. For example, in the Woodland study under drought imposed at flowering hybrids released in the 1940s (N=6) yielded 2.20 t/ha vs. 7.19 t/ha for hybrids from the 1990s (N=11), a 227% or 4.99 t/ha increase. Under grain filling stress the respective yields were 4.97 t/ha and 8.69 t/ha, a 3.72 t/ha or 75% increase, while under well-watered conditions they were 9.85 t//ha vs. 13.90 t/ha, a 4.05 t/ha or 41% increase. Gains were surprisingly similar across water stress levels in this study, but proportionally much greater for stress imposed at flowering. Improvements were almost exclusively through increases in kernel set under mid-season stress, initially from reduced barrenness and later from improved kernel set per ear. In a simulation study using similar data Hammer et al. (2009) noted that improved yields can only come from increased water capture in modern hybrids, something that they attributed to deeper rooting. The efficiency of applied irrigation water to generate grain has tripled from the 1940s to the 1990s through improvements in yield potential, increased water capture and drought tolerance (Butzen and Schussler, 2009). There is continuing evidence that drought tolerance in modern Corn Belt germplasm is linked to rooting volume and intensity (http://www.asgrowanddekalb.com/products/corn/Pages/rootdig.aspx). Field data based on evaluation the ERA hybrid subset suggest that conventional genetic variation for staygreen under terminal drought stress (Edmeades et al. 2006) and tolerance of high temperature spikes at flowering and during grain filling may be insufficient to provide selection gains. These traits may ultimately depend on transgenic sources of variation for rapid change.

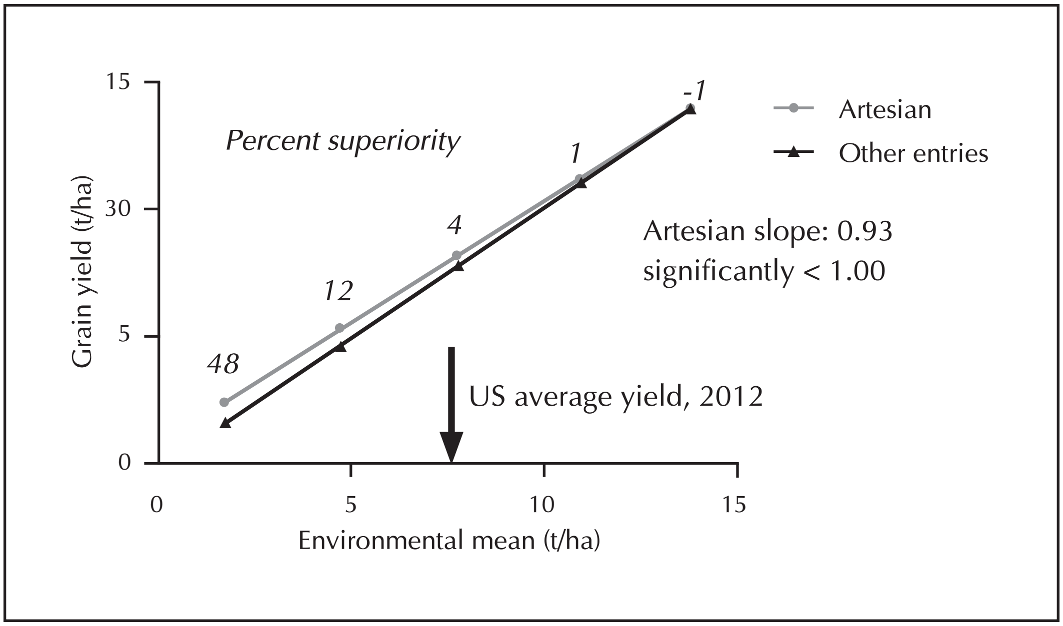
Molecular breeding methods show considerable promise for accelerating these historical gains – providing genetic variation is adequate. Eathington et al. (2007) and Edgerton (2009) have indicated that selection schemes similar to MARS have virtually doubled the rate of genetic gain in Monsanto's maize populations. Pioneer's "mapping as you go" presumably offers similar rates of increase in genetic gain in the context of a regular pedigree breeding program (Podlich et al. 2004). Association mapping and genomic selection have come more easily and quickly to the large commercial companies vs. the public sector because of their capacity to synchronize phenotyping and genotyping, massive capacity to field test mapping populations, extensive bioinformatics capability, and access to capital and elite germplasm (see Eathington et al. 2007; Edgerton, 2009; Schussler et al. 2011). In addition, the capacity for generating DH lines in large multinationals exceed 500,000 annually, significantly shortening the time for generating inbreds and improving the precision of comparison among lines and top crosses. The development of seed chipping methods allows DNA of DH lines to be assessed non-destructively, and undesirable DNA combinations are discarded – before ever being observed as plants. The combination of DHs, with seed chipping and genomic selection based on genotyping by sequencing or dense marker arrays has the potential to almost halve effect the generation interval and sharply increase the selection pressure, thereby “speeding the breeding” dramatically. The combination of these techniques, with a large increase in managed stress testing locations equipped with remote sensing capability for phenotyping means that genetic gains for drought tolerance may be more than double those from the 1930-2000 period (Edgerton, 2009).

Conventional native gene drought tolerant products: Drought tolerant hybrids selected using some or all of the above techniques have been available in the US market since 2011. Assessing performance is challenging in the absence of independent head to head comparisons. Yields of drought tolerant hybrids are often compared with an undisclosed list of “leading competitor hybrids” that may be several years old, and the comparison is certainly open to bias. Given this caveat, Syngenta’s Agrisure Artesian™ hybrids, based on a series of 12 QTL that operate across a wide range of genetic backgrounds (http://www.freepatentsonline.com/y2011/0191892.html). Around half of these QTL have been obtained from non-Corn Belt sources. During the 2012 growing season when drought affected much of south and central US these hybrids Syngenta reported a significantly improved performance under severe stress (12% superiority in yields in the 3.1-6.2 t/ha range; 48% in yields less than 3.1 t/ha) (Figure 5). At yield levels of around 50% of potential (or 6.9 t/ha) the advantage is predicted to 0.4 t/ha or 6%.

A second company, Pioneer Hi-Bred launched a line of hybrids under the AQUAmax™ brand in 2011, developed from native gene selections using a QTL-based approach termed Accelerated Yield Technology™. This variant on genomic selection appears to use dense molecular maps, multilocation testing and markers as heritable covariates to focus on hotspots in the genome (Sebastian, 2009). It operates with DH lines whose topcrosses are selected under managed stress environments. In 2012 extensive testing was undertaken in 3606 water limited and 7663 favorable environments. Over both 2011 and 2012 seasons side by side comparisons against competitive products show 8.9% superiority in water limited environments (less than 9.4 t/ha) and a 1.9% advantage in favourable growing conditions (greater than 11.3 t/ha) (http://www.4-traders.com/news/Pioneer-Hi-Bred-International-Inc) . AQUAmax hybrids are characterized by vigorous silking and improved staygreen. As with the Artesian hybrids and with the ERA hybrids described above, relative gains are greater under severe stress, and there is no yield penalty in optimum conditions. Artesian and AQUAmax hybrids will undoubtedly feature strongly in 2013 sales of both companies.

Although not identified under a brand name as such there is little doubt that Monsanto, DowAgrosciences and many other companies are developing conventionally-selected

Figure 5. 2012 yield of Agrisure Artesian™ hybrids in 1100 on farm strip trials in the US vs. an environmental mean comprising yields of control hybrids with and without putative drought tolerance. (http://www.syngentacropprotection.com/news_releases/)



drought tolerant maize hybrids for the temperate market. Several have performed well in isolated trials against trademarked drought tolerant products (e.g., http://www.asgrowanddekalb.com/products/corn/pages/rootdig.aspx).

Continued gains in public and private sector programs depend the availability of adequate genetic variation, and faster rates of genetic progress may simply exhaust genetic variation more rapidly. New sources of genetic variation likely exist in germplasm collections, though these are hard to evaluate and utilize because of linkage drag from unimproved and narrowly adapted sources. Programs such as Seeds of Discovery, funded by the Government of Mexico, are providing advanced tools for identifying stress-tolerance alleles in CIMMYT's quite considerable germplasm collection (http://masagro.mx/index.php/en/components-en/seeds-of-discovery).

Transgenic drought tolerant products: As in 2008, a survey of published literature and of company websites was undertaken, but does not reveal the detail and extent of private sector investments in transgenic research for drought tolerance. The level of activity is gauged by public disclosures of a few leading companies. Drought tolerance is a genetically complex trait, so it is reasonable to expect that a successful transgenic strategy will rely on transcription factors and cascades of genes, or transformation with several transgenes affecting different but key processes. However, current attempts appear to be focused on single genes.

Monsanto remains the leader in transgenic research for drought tolerance in maize, and is scheduled to commence commercial sales of transgenic Droughtgard™ hybrids in 2013. The construct has recently been approved for sale for food and feed in the US and EU countries. Monsanto's event, MON87460, contains a cold-shock protein gene (*cspB*) isolated from *Bacillus subtilis*, a soil bacteria. The gene is thought to code for a protein that acts as a chaperone to other more stress-sensitive proteins such as RNA (Castiglioni et al., 2008), and although it appears be active throughout the life of the plant, its effect on yield is mainly by increasing kernel number per plant. The level of improvement it brings depends on the genetic background of the recipient hybrid and the environment. The complexity of these gene x genotype and G x E interactions have delayed its release as a commercial product. After the dry 2012 season Monsanto has indicated, based on over 2000 comparisons, that adapted hybrids carrying MON87460 provide 5 bu/acre (0.31 t/ha) yield advantage, or about 7% under drought that reduces yields by around 65% to 4.4 t/ha. In some genetic backgrounds its effect can be considerably greater than this (http://www.biofortified.org/2012/08/monsantos-gm-drought-tolerant-corn/). Its benefits appear to be from slowing growth (and hence water use), thereby saving water, maintaining photosyntheisis and increasing kernel numbers per plant. It does not appear to reduce yields under unstressed conditions. This event is also on a deregulation pathway in South Africa, Kenya and Uganda. Additional classes of transgenes are under test by BASF and Monsanto who collaborate in this research. However, no obvious successor to MON87460 has yet been revealed. Meanwhile Monsanto continues collaboration in drought tolerance gene discovery, validation and delivery with BASF and with Evogene, an Israeli company specializing in computational genomics.

Other major seed companies are also pursuing transgenic drought tolerance in maize. Pioneer Hi-Bred have conducted an active research program on transgene-based drought tolerance for the past decade. Now all transgenes are compared with AQUAmax hybrids for effectiveness, and the commercial timeline, given in 2008 as potentially 2013, has been pushed out to further towards the end of this decade. Transgenes would need to complement the drought tolerance provided through AQUAmax to provide a "Stage 2" drought tolerance product. Pioneer has collaborated with Evogene and several other gene discovery companies in the past. Syngenta has a relatively smaller research effort in transgenic drought tolerance, and anticipate a commercial release in 2015. Syngenta signed a research agreement with Performance Plants Inc. for access to their YPT technology (see below) but the outcome of the collaboration is not known. Their testing sites under managed stress are significantly less developed than those of Monsanto and Pioneer. Dow AgroSciences is increasing its investment in native and transgenic sources of drought tolerance in their maize breeding programs (http://mobile.dow.com/news/press-releases/article/?id=6118), seeking to capitalize on their Smartstax® technology that allows insertion of up to eight transgenes simultaneously.

Other gene discovery companies generally license genes to the major maize seed companies to provide introgression, field testing and regulatory services. These include Bayer who is researching genes that reduce the drought-induced oxidant load that leads to tissue and DNA damage (e.g., RNAi poly ADP-ribose polymerase, or PARP). It is unclear how this product performs in maize and if there is commercial interest for maize. Performance Plants Inc. is a small Canadian company that patented its Yield Protection Technology (YPT) around 2006. YPT relies on engineered versions of farnesyl transferase genes that increase sensitivity to ABA thereby closing stomates rapidly when the plant stresses. YPT has shown good activity in canola and cotton, but only modest effects in maize under drought. Performance Plants also provides transgenes that are claimed to protect against heat and to enhance WUE. In the past it has had research agreements established with Syngenta and Pioneer, and claims that a drought tolerant variety of maize has been field tested for two years. Other candidate genes include members of the DREB/CBF transcription factor family (Yamaguchi-Shinozaki et al. 2006). These have shown efficacy at the seedling stage, but their value for increased grain yield in maize or wheat in the field has yet to be demonstrated.

There are many, perhaps thousands, of putative drought genes, but most have been found wanting. Many have shown some level of activity in seedlings or in greenhouses but have unacceptable levels of yield drag under unstressed conditions – a fatal flaw in a commercial hybrid. Others have failed when taken to the field and tested in real-life situations in full-sized plants that are flowering and setting grain under stress. Some do not actually improve stress tolerance but merely delay the onset of stress in pots because their growth is stunted and their water consumption reduced (Lawlor, 2012). Very few have regulatory packages associated with them. As we noted in 2008, identification of commercial-quality transgenes that enhance both survival under drought and production under adequate water supply is a lengthy, tedious and expensive process. At that time it was felt that the success rate in identifying suitable candidate genes was bound to increase as genomics and computational biology began to deliver powerful new analytical tools. This does not appear to have happened to the degree anticipated, and few breakthroughs can be reported in 2012.

4. Product delivery: its hurdles and successes

Changes since 2008 in product delivery have been slower than those in product development, and will only be summarized here. In developed countries adoption will depend mainly on the prices of seed and grain, superior and stable yield under drought and competitive yield under unstressed conditions. Seed is easily available, and information on the benefits of the product is readily accessed. Risk is relatively small, and crop insurance schemes ensure that farmers rarely face ruin from drought.

In less developed countries, however, the distribution and adoption of drought tolerant hybrids and varieties remain major constraints to their use. Seed of improved hybrids is often difficult to obtain, and farmers often face levels of risk to family incomes and food security that dwarf those faced in the developed world. At the same time, resource poor farm families have very limited capacity to accommodate risk, even though they are fully aware of profitability considerations (Heisey and Edmeades, 1999). Sources of risk are many, but a major one is drought superimposed on already low yield levels. Access to credit at reasonable rates is another so the outlay of cash for hybrid seed and fertilizer at the start of the season is especially challenging. The greater the perceived risk from drought, the more likely the farmer is to use his own saved seed and fewer inputs. Farmers will therefore often resort to sowing an open-pollinated variety (OPV) or seed saved from last year's hybrid harvest, even though it can be demonstrated that the risks of crop failure can be reduced by exploiting heterosis in stress-tolerant hybrids (e.g., Betrán et al. 2003).

Private seed companies are the preferred means of distributing drought tolerant hybrids, provided sufficient profit can be made from hybrids marketed into lower yielding and risky drought-prone regions. Experience suggests that yields of greater than ~2 t/ha provide a reasonable return on the cost of hybrid seed that is being produced for sale as cheaply as possible (Pixley, 2006). Circumstances resulting in yields of 2 t/ha from a drought tolerant hybrid will often lead to yields of 1 t/ha or less in an unimproved farmer variety, so this becomes a win-win situation. The deployment of drought tolerance in the form of hybrids has many benefits. Commercial seed quality and seed treatments are generally better than those of home stored seed, thus reducing risk of failed plantings. The generation and sale of hybrid maize seed, as opposed to seed of OPVs, has provided the foundation for a viable and stable seed industry – an essential step in development of a stable seed industry. Public and private seed companies in less developed countries are hampered by a lack of trained staff and quality-enhancing competition, by credit constraints, a weak infrastructure for distributing and marketing product, and inappropriate seed policies. As a consequence the maize seed industry in much of sub-Saharan Africa is still unable to offer consistent and well-tested hybrid seed options to small-scale farmers. As noted in 2008, until mean yield levels increase substantially, there remains a need for a diversity of seed systems that deliver drought tolerant hybrids and varieties – including NGOs, Government agencies, Universities and private seed companies.

Transgenic drought tolerance is encountering additional adoption challenges in less developed countries, mainly because the regulatory framework is still evolving. Under the auspices of the

WEMA Project, both MON87460 and MON810 (Bt insect resistance) are in the confined field trial testing stage in Uganda and Kenya, while attempts are being made to establish the legal framework for these trials in Tanzania and Mozambique.

a. **Public sector:** While CIMMYT and IITA maize breeding programs have fully adopted pedigree breeding systems for hybrid development, there is still some demand in sub-Saharan Africa for OPVs as an intermediate step to generate confidence among farmers. Such OPVs are easily developed within a pedigree breeding system. Distribution of OPV seeds can be by farmer to farmer transfer, and seed can be recycled for several generations without loss of performance. The Mother-Baby trial system has been successfully used in southern and eastern Africa as a means of generating farmer participation in selection, adoption and seed production (Bänziger and DeMeyer, 2002) resulting in outstanding drought tolerant OPVs such as ZM521, ZM409 and ZM523. The generation and distribution of OPV seed must be seen today as a transitional step to hybrid production and sales since the formation of a viable seed sector will depend ultimately on hybrids sold each crop season rather than OPVs sold only periodically. Thus a major goal of DTMA and WEMA Projects is to strengthen the emerging private seed sector. More than 100 seed companies operating in sub-Saharan Africa north of South Africa are actively participating in testing and marketing drought tolerant hybrids developed in collaboration with DTMA and WEMA. South Africa has a mature maize seed industry, and is now providing advice to emerging companies in the rest of the region.

   In the meantime, the DTMA Project has produced conventionally selected hybrids that are passing through the release process – 15 in Kenya and 6 in Uganda, as well as several OPVs in West Africa. WEMA has nominated 16 hybrids in Kenya, 8 in Uganda and 5 in Tanzania to National Performance Trials. There are several drought tolerant hybrids already released by collaborating private seed companies in the regions that contain all or some lines derived from CIMMYT's long involvement in the region. WEMA has developed a strong emphasis on licensing lines to private seed companies in eastern and southern Africa, and this will help adoption while strengthening the private seed sector. It is hoped that in the next 2-3 decades the whole process of hybrid development can be handed over to the private seed sector.

b. **Private sector:** Product delivery in the developed world is efficient and effective. The availability of information is perhaps excessive and a farmer has to choose carefully among products, using information from independent head to head comparisons, e.g., Iowa Crop Improvement Association Corn Performance trials (http://www.croptesting.iastate.edu/). The costs and time involved in developing and deregulating transgenes means that only the well-resourced companies can undertake this step, variously estimated to cost up to $100 M per gene.

In the less developed world, transnational maize seed companies (Monsanto, Pioneer, Syngenta, and to a lesser degree regional companies such as Pannar, SeedCo, Kenya Seed Company and Pacific Seeds) are represented in most of the larger, higher yield potential markets. They have an advantage over national seed companies in that they have extensive and well-resourced research capacity, have extensive networks of technology suppliers, and can transfer adapted germplasm from one country to another to reduce product development overheads. However, because transnational seed companies operate only in the larger markets in areas where yields are relatively high, there is a good opportunity for national seed companies to establish a market niche comprising smaller market segments, and meet real needs through a balanced portfolio of stress tolerant hybrids and elite OPVs. No matter what the size distribution of private seed companies may be, a healthy, expanding, diverse and profitable private seed sector is essential for the sustained improvement and delivery of drought tolerant hybrids to farmers in regions such as sub-Saharan Africa and South Asia. Programs such as PASS (Program for Africa's Seed Systems, see http://www.agra-alliance.org/what-we-do/seed/) are playing a leading role in strengthening the domestic private seed sector in sub-Saharan Africa.

c. **Private/public partnerships:** Partnerships between private and public sector research organization are a strategy often proposed but rarely executed. WEMA is an important joint venture of this nature involving Monsanto as the main technology provider, CIMMYT as the source of key phenotyping sites and adapted maize germplasm, and national programs and seed companies as partners in testing and delivery. The African Agricultural Technology Foundation (AATF), a Nairobi-based not-for-profit organization, serves as the implementing agency, and will spearhead efforts to ensure regulatory compliance of MON87460 in target countries. WEMA has completed its first 5 year phase, with a further 5 years approved. Monsanto, CIMMYT and national programs are working together on MAS and conventional selection, building on Monsanto's extensive capabilities in doubled haploid line generation, molecular markers and bioinformatics in germplasm supplied by CIMMYT from DTMA or donated by Monsanto. Phenotyping is shared between CIMMYT and Monsanto. MON87460 and MON810 have been provided by Monsanto on a royalty free basis for use in Kenya, Uganda, Tanzania, Mozambique and South Africa – the latter under special circumstances to small-holders only. Monsanto is carrying a large proportion of the load in helping these national programs build a system to deregulate and introgress these transgenes into adapted lines from CIMMYT. As with temperate hybrids, it has proved challenging to find a suitable genetic background for MON87460, and this is made more difficult by testing which is limited to 1-2 confined field trial sites per country. The early hopes of a 15% boost in yields under stress from this transgene have been replaced with a more modest expectation of 10%. Nonetheless, impact from conventionally improved hybrids should be felt within the next two years as released hybrids are taken up, and should be substantial. South Africa will be the first African country to benefit from transgenic drought tolerance. The time line for release there could be as early as 2015, and 2017 in Uganda and perhaps Kenya.

The WEMA partnership in eastern and southern Africa presents a unique and important opportunity to bring modern technology to address drought tolerance for the poor, and will help put in place the regulatory procedures needed to bring other transgenes to this needy region. Aligning the cultures of the collaborating institutions has taken time, but the synergistic benefits of wholehearted private-public collaboration are now being felt. Based on the WEMA model the Gates Foundation have supported a similar initiative, Improved Maize for African Soils (IMAS) that aims to combine N efficient conventionally selected lines with a transgene being developed by Pioneer Hi-Bred that will improve N use efficiency significantly. In both WEMA and IMAS an issue arises over the action of the transgene. In both projects the transnational private company will only supply transgenes that have been deregulated for use as food and feed in the US, Europe and Japan. Many transgenes have significant effects in very dry or infertile soils but carry some yield penalty in optimal conditions, thus rendering them unattractive commercially. While they would be very suitable for use by African farmers, African national programs could not afford the full deregulation package if not paid for by the US donor company. Despite challenges of this nature, private-public partnerships must continue to be fostered as a win-win proposition for national programs, private seed companies and most importantly the African farm family.

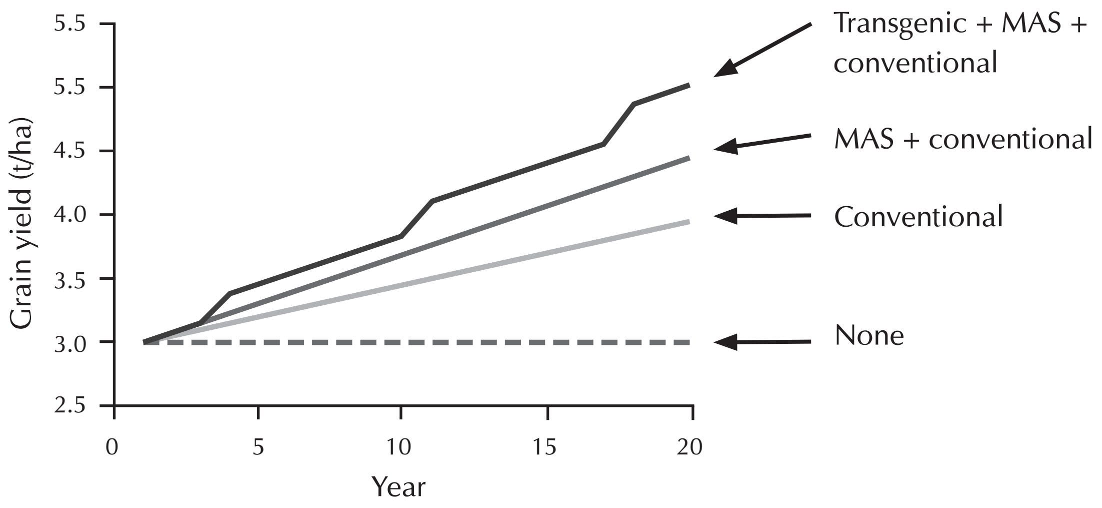
5. Onwards and upwards? The way forward

a. **Expected rates of gain in yield:** There is less optimism and more pragmatism in projections in 2012 vs. those of 2008. Published gains from directed selection solely for drought tolerance average around 100 kg/ha/yr (Section 3b), but drought tolerant hybrids also require improved or maintained disease and insect resistance, stalk strength, correct maturity and appropriate grain quality. Estimates of realistic rates of gain under drought from conventional selection in a commercial context have therefore been reduced to 50 kg/ha/yr. Marker-assisted breeding, when well executed, can double gains from conventional selection (Edgerton, 2009), and successes with Artesian™ and AQUAmax™ hybrids generally support this contention. Rates of improvement from public sector MAS breeding in schemes such as DTMA and WEMA are still being measured, but there are challenges in managing genomic selection in real time in the less developed world. The increased rate of gain of [MAS + conventional] over conventional selection alone have accordingly been dropped to 50%.

The results from transgenic drought tolerance have also been reduced. Gains from MON87460, with some unique exceptions, now look to be 5% across a range of genetic backgrounds, and the delay in announcements of new drought tolerance transgenes and timelines for commercialization by major companies speak for themselves. It is assumed that a realistic assumption would be a new transgene providing 5% yield gain every eight years rather than the 2008 assumption of one new gene giving 15% boost in yield every five years. Gains from each interventional are built on a base yield of 3 t/ha – a level considered and average for drought affected maize in temperate and tropical production environments. It is assumed that gains from each technology are additive (Figure 6), and this results in annual average gains of 50, 75 and 106 kg/ha/yr under conventional, [conventional + MAS] and [conventional + MAS + transgenics], or rates relative to mean yields of 1.4, 2.0 and 2.7% annually. This gives an average additional gain due to transgenes of around 30 kg/ha/yr – a figure which new technologies may well double in the future.

Thus, in resource intensive programs such as those conducted by multinational seed companies, these rates should be somewhat greater. Historical rates of increase in yield under managed drought in Pioneer's ERA hybrid set are reported as 72 kg/ha/yr (Schussler et al. 2011), so directed selection with MAS may well double this rate of gain in this germplasm. However, in general, going forward it seems wise to depend on rates of improvement under

Figure 6. Projected cumulative yield gain over a 19 year period in maize being selected for drought tolerance using conventional selection methods (50 kg/ha/yr), [marker-aided selection (MAS) + conventional] (75 kg/ha/yr) and [One transgene introduced every 8 years + MAS + conventional]. Each transgene added boosts grain yield by a cumulative 5%. Effects of each intervention are considered additive.



drought of around1-2%/yr and 50-80 kg/ha/yr in less well resourced breeding programs that address needs of whole regions where rates of gain are slowed by G x E interactions.

b. **Role of the private, public and private + public sectors:** The public sector has played a large and important role in refinement of techniques, proof of concept, improved sources of drought tolerance, and germplasm collections to provide future genetic variation. This has been boosted by the substantial investment of the Gates Foundation and the 38 year leadership of CIMMYT in developing and disseminating drought tolerant maize (Bänziger et al. 2006). These roles should continue in areas where the private sector is poorly developed, and for clients in risky and low yielding environments. Research of this nature is a relatively slow process. Hybrids take 7-15 years from the initial cross to the onset of adoption, so a program that consistently delivers drought tolerant hybrids requires committed resources over several decades to be successful – something that is difficult to accomplish in the public sector today. To accelerate the process using MAS, the latest marker technologies, DHs, transgenes and bioinformatics requires substantial investments to reach a critical mass, something rarely found today in the public sector. A decade-long investment of US$3.5 billion in genetically modified crops by China is an example of this commitment (Stone, 2008). With this exception, public sector investments are dwarfed by those made in the private sector.

   As the need and opportunity arise to speed up rates of gain in maize, the public sector must form alliances with the private sector, or allow the private sector to take over a large part of the MAS and genetic modification responsibilities this will entail. By so doing the development of the crop is linked to an efficient and sustained distribution sytem, and market forces will dictate the research. Clearly the public and private sectors need to combine efforts based on their relative strengths, and this will require clear leadership and clear benefits for all partners involved, without overlooking the poorest of poor families in low yielding risky rainfed environments. A careful analysis of the factors leading to success of projects such as WEMA and DTMA is needed so we learn from these very important initiatives and replicate their success. The Standard Material Transfer Agreement (SMTA) adminsitered by FAO that governs the level of royalties paid to countries to whom the germplasm originally belonged will affect the willingness of some private seed companies to use CIMMYT germplasm. The impact of this royalty charge on the commercial use of CIMMYT germplasm is not yet known.

c. **Centers of excellence in phenotyping, product development and delivery:** The value of MSEs for efficient drought selection in maize has been consistently demonstrated over the past 20 years (Bänziger et al. 2006) and has been adopted by leading commercial companies as well. For less developed countries long term funding to maintain and expand existing publicly funded regional centers of excellence in phenotyping for drought tolerance, such as that at Kiboko, Kenya, seems fully justified. A similar argument can be made for regional centers to generate DH lines (recently approved by Gates Foundation) and for foundation hybrid seed to meet the needs of smaller seed companies and public national breeding programs. Public funding used in this way must be considered transitional en route to a a full cost recovery and eventual privatization of each of these functions, though this may be several decades away.

d. **New genetic variation – the role of transgenics:** Although there has been a an apparent slow down in the number of drought-related transgenes coming to market over the past four years, this should be considered temporary. The identification of genes with small effects on drought tolerance continues at a rapid pace. Methodologies such as Smartstax® that allows up to eight transgenes to be located together ("stacked") so they segregate as a block, suggests a multigene approach to drought tolerance may be feasible. The capacity for addition and deletion of transgenes to or from specific genomic locations is rapidly improving. Small RNA fragments are emerging as powerful control elements of stress response in plants (Sunkar et al. 2007).

   The promise of transgenic technologies is, however, being threatened by uncoordinated over-regulation. Unfortunately the biosafety framework leading to ordered testing and deregulation in sub-Saharan Africa is being developed country by country when a regional approach would be a far more efficient use of resources. Present systems are modelled on risks that experience suggests are overestimated. They are onerous and expensive to implement, and beyond the reach of the vast majority of institutions in the less developed world. James (2011) considers the lack of appropriate science-based cost- and time-effective deregulation based on actual risks involved is the most important constraint to the deployment of genetically modified crops. The recent ban by the Government of Kenya on the sale of genetically modified food (http://allafrica.com/stories/printable/201211301197.html), and the introduction of strict liability for developers and users of GM crops in Tanzania are both slowing the use of this important technology under the pretext of the need to gather more information on its risks. Thus the precautionary principle on transgenic crop regulation in its present form is hurting resource-poor farm families -- the very people it was designed to protect, and forcing the development of transgenics back into the hands of a few large well-resourced institutions.

e. **Agronomic interventions:** Improved crop management methods can complement the use of drought tolerant hybrids and contribute significantly to increasing and stabilizing yields under rainfed conditions or under irrigation where water supply is limited. Conservation agriculture, a collection of practices embodying the use of reduced or zero tillage and mulch to reduce evaporation of soil water, is an obvious means of increasing water available to the maize crop (Thierfelder et al. 2012). The use of plastic mulch in dry cool areas on the Loess Plateau of China has markedly increase WUE in maize (Fan et al. 2005). Drip irrigation can also reduce evaporative losses and deficit irrigation can increase WUE, often at little cost to yield (Fereres and Soriano, 2007).

6. Conclusions

As in the 2008 review, it is clearly possible to improve drought tolerance at no cost to yield under optimal conditions. There is an increasing interest in drought tolerance, and the trait can be improved relatively easily in maize. The use of representative managed stress environments is again endorsed, as well as the ongoing need for public private partnerships. The requirement for sustained investment in drought tolerance, given the 7-15 year cycle for hybrid development, is strongly endorsed.

Other issues that have changed in importance since 2008:

- Genetic gains from manipulating native genes can only increase in the future. There has been a large increase in genome-wide association studies and the emergence of practical methods for genomic selection, meaning that native gene variation can be exploited more rapidly. Nakaya et al. (2012) state that although genomic selection is not perfect it is becoming a potent and valuable component of plant breeding. In the short-term gains in drought tolerance will come largely from native genes, and this will increase the need to identify new alleles that can sustain these. Germplasm collections are assuming greater importance.
- The transgenic route to drought tolerance has proven more difficult than first hoped. This is mainly because of the lack of genes with large effects, yield drag, gene x genotype and G x E interactions, and the decentralized nature and expense of the regulatory process and its enforcement in sub-Saharan Africa. In practice this mean that genes with small effects and limited market value are quickly abandoned.
- Tremendous progress has been made in the past four years in developing drought tolerant products – both in temperate and in tropical maize. The 2013 season will be a signal year – with Droughtgard™, AQUAmax™ and Agrisure Artesian™ hybrids on the market, and a large number of drought tolerant hybrids going through the release process in sub-Saharan Africa.
- Solid progress is recorded in regional approaches to developing drought tolerant germplasm in sub-Saharan Africa and in south Asia. If these regional initiatives and harmonization of regulations can be extended to release of improved hybrids and the deregulation of transgenes, these regions could see rapid development in their agricultural sectors.
- Efficient and accurate phenotyping is essential. While considerable progress in remote sensing methodologies has been observed over the past four years, in sub-Saharan Africa

the need is simpler – trained support and effective mechanization of basic plot operations.

- Heat stress is receiving considerably more research attention, and although heat and drought often occur together, tolerance to each appears to be independent of the other.
- Selection for drought tolerance depends on dedicated staff who will stay in the field in the heat. They need to be adequately trained, supported and encouraged, then left to do what they do well, without institutional distractions that are so common in the developing world.
- The climate is changing, and the need for stable stress tolerant crop varieties and hybrids has never been greater. The tools and germplasm currently available, and the emerging private-public partnerships in crop development will be more than adequate to meet this challenge as long as our resolve does not falter and we use our resources wisely.

7. Acknowledgments

Thanks are due to Dr. Clive James for commissioning and supporting this brief review. The helpful advice of Drs. Walter Trevisan, Raman Babu, Mark Cooper, Hugo Campos, Renee Lafitte, Abebe Menkir, B.M. Prasanna, and Dr. Chris Zinselmeier is gratefully acknowledged. The errors and judgements included in the paper are however, all my own.

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Future Prospects, 2013 to 2015, the MDG year

The adoption of biotech crops in the three–year period 2013 to 2015 will be dependent on three factors:

- first, the timely implementation of appropriate, responsible and cost/time-effective regulatory systems;
- second, strong political will and enabling financial and material support;
- and third a continuing wave of improved biotech crops that will meet the priorities of industrial and developing countries in Asia, Latin America and Africa.

The outlook for biotech crops in the remaining 3 years of the second decade of commercialization, 2013 to 2015, is assessed as cautiously optimistic. Following a credible growth of 6% in 2012, a phase of consolidation of gains to-date can provide the broad foundation to support future growth in the remaining years of the second decade of commercialization (2006 to 2015) and beyond. Two new developing countries Sudan and Cuba joined in 2012, and three more countries from Asia are likely to join before 2015. In addition there are several candidate countries in sub-Saharan Africa, which could join before 2015, all of which are subject to regulatory approval, which is the most significant constraint to commercialization. Most countries in Latin America have already commercialized biotech crops and the EU region is a particularly difficult to predict because the issues are not related to science and technology considerations but are of a political nature and influenced by ideological views of activist groups. A biotech potato resistant to late blight, (Fortuna) offers an attractive and appropriate near term opportunity for selected potato-growing countries in the EU to join the growing number of countries benefiting from biotech crops globally. Herbicide tolerant sugarbeet is also a candidate for the EU, and has the advantage that it is already commercialized in the US and Canada and has gained broad approval from the major sugar importing countries

There is considerable potential for increasing the adoption rate of the four current large hectarage of biotech crops (maize, soybean, cotton, and canola), which collectively represented 170 million hectares of biotech crops in 2012 from a total global potential of ~320 million hectares. Thus, there are approximately 150 million hectares for potential adoption, of which over 30 million hectares of maize are in China where demand for maize as a feed crop is growing fast, as the country consumes more meat. In the near and mid-term the timing of the deployment of biotech maize and rice, as crops, and drought tolerance as a trait (first in maize in 2013 and later in other crops) are seminal for catalyzing the further adoption of biotech crops globally. In contrast to the first generation biotech crops that realized a significant increase in yield and production by protecting crops from losses caused by pests, weeds, and diseases, the second generation biotech crops will offer farmers additional new incentives for also improving quality of products. For example, quality traits, such as enhanced Vitamin A in rice, soybean free of trans-fat and reduced saturated fat, and omega-3 rich soybean, will become more prevalent, providing a much richer mix of consumer-friendly traits for deployment in conjunction with a growing number of input traits. Biotech sugarcane is likely to be available in the near term. Five years ago in North America, a decision was made to delay the introduction of biotech herbicide tolerant wheat, but this decision has been revisited. Many countries and companies are now fast-tracking the development of a range of biotech traits in wheat including drought tolerance, disease resistance and grain quality. The first biotech wheat is expected to be ready for commercialization before 2020.

The contribution of biotech crops to Sustainability

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations, 1987).

Biotech crops are already contributing to sustainability and can help mitigate the effects of climate change in the following five ways and have enormous potential for the future:

- **Contributing to food, feed and fiber security and self sufficiency, including more affordable food, by increasing productivity and economic benefits sustainably at the farmer level**

  Biotech crops already play an important role by increasing productivity per hectare and coincidentally decreasing cost of production as a result of reduced need for inputs. Economic gains at the farm level of ~US$98.2 billion were generated globally by biotech crops during the sixteen year period 1996 to 2011, of which 51% were due to reduced production costs (less ploughing, fewer pesticide sprays and less labor) and 49% due to substantial yield gains of 328 million tons. The 328 million tons comprised 110.2 million tons of soybean, 195 million tons of maize, 15.8 million tons of cotton lint, and 6.6 million tons of canola over the sixteen year period 1996 to 2011. For 2011 alone, economic gains at the farm level were US$19.75 billion, of which approximately 22%, were due to reduced production costs (less ploughing, fewer pesticide sprays and less labor) and approximately 78%, due to substantial yield gains of 50.2 million tons. The 50.2 million tons comprised 12.74 million tons of soybean, 34.54 million tons of maize, 2.48 million tons of cotton lint, and 0.44 million tons of canola (Brookes and Barfoot, 2013, Forthcoming). Thus, biotech crops are already making a contribution to higher productivity and lower costs of production of current biotech crops, and have enormous potential for the future when the food staples of rice and wheat, as well as pro-poor food crops such as cassava, will benefit from biotechnology.

- **Conserving biodiversity, biotech crops are a land saving technology**

  Biotech crops are a land-saving technology, capable of higher productivity on the current 1.5 billion hectares of arable land, and thereby can help preclude deforestation and protect biodiversity in forests and in other in-situ biodiversity sanctuaries. Approximately 13 million hectares of biodiversity – rich tropical forests are lost in developing countries annually. If the 328 million tons of additional food, feed and fiber produced by biotech crops during the period 1996 to 2011 had not been produced by biotech crops, an additional 108.7 million hectares of conventional crops would have been required to produce the same tonnage. Some of the additional 108.7 million hectares would probably have required fragile marginal lands, not suitable for crop production, to be ploughed, and for tropical forest, rich in biodiversity, to be felled to make way for slash and burn agriculture in developing countries, thereby destroying biodiversity. Similarly, for 2011 alone, if the 50.2 million tons of additional food, feed and fiber produced by biotech crops during 2011 had not been produced by biotech crops, an additional 55.5 million hectares of conventional crops would have been required to produce the same tonnage for 2011 alone (Brookes and Barfoot, 2013, Forthcoming).

- **Contributing to the alleviation of poverty and hunger**

  Fifty percent of the world's poorest people are small and resource-poor farmers, and another 20% are the rural landless completely dependent on agriculture for their livelihoods. Thus, increasing income of small and resource-poor farmers contributes directly to the poverty alleviation of a large majority (70%) of the world's poorest people. **To-date, biotech cotton in countries such as China, India, Pakistan, Myanmar, Burkina Faso and South Africa have already made a significant contribution to the income of ~15 million poor farmers in 2012, and this can be enhanced significantly in the remaining 3 years of the second decade of commercialization, 2013 to 2015 principally with biotech cotton and maize.** Of special significance is biotech rice which has the potential to benefit 250 million poor rice-growing households in Asia, (equivalent to one billion beneficiaries based on 4 members per household) growing on average only half a hectare of rice with an income as low as US$1.25 per day – they are some of the poorest people in the world. It is evident that much progress has been made in the first fifteen years of commercialization of biotech crops, but progress to-date is just the "tip of the iceberg" compared with potential progress in the second decade of commercialization, 2006-2015. It is a fortunate coincidence that the last year of the second decade of commercialization of biotech crops, 2015, is also the year of the Millennium Development Goals (MDG). **This offers a unique opportunity for the global crop biotechnology community, from the North and the South, the public and the private sectors, to define in 2013 the contributions that biotech crops can make to the 2015 Millennium Development Goals and also a more sustainable**

agriculture in the future – this gives the global biotech crop community five years to work towards implementing a global strategy and action plan for biotech crops that can deliver on the MDG goals of 2015.

- **Reducing agriculture's environmental footprint**

  Conventional agriculture has impacted significantly on the environment and biotechnology can be used to reduce the environmental footprint of agriculture. Progress to-date includes: a significant reduction in pesticides; saving on fossil fuels; decreasing CO_2 emissions through no/less ploughing; and conserving soil and moisture by optimizing the practice of no till through application of herbicide tolerance. The accumulative reduction in pesticides for the period 1996 to 2011 was estimated at 473 million kilograms (kgs) of active ingredient (a.i.), a saving of 8.9% in pesticides, which is equivalent to a 18.3% reduction in the associated environmental impact of pesticide use on these crops, as measured by the Environmental Impact Quotient (EIQ) – a composite measure based on the various factors contributing to the net environmental impact of an individual active ingredient. The corresponding data for 2011 alone was a reduction of 37 million kgs a.i. (equivalent to a saving of 8.5% in pesticides) and a reduction of 22.8% in EIQ (Brookes and Barfoot, 2013, Forthcoming).

  Increasing efficiency of water usage will have a major impact on conservation and availability of water globally. Seventy percent of fresh water is currently used by agriculture globally, and this is obviously not sustainable in the future as the population increases by almost 30% to over 9 billion by 2050. The first biotech maize hybrids with a degree of drought tolerance are expected to be commercialized by 2013 in the USA, and the first tropical drought tolerant biotech maize is expected by ~2017 for sub-Saharan Africa. The advent of drought tolerance in temperate tropical maize in the industrial countries will be a major milestone but will be of even much greater significance in tropical maize in sub-Saharan Africa, Latin America and Asia. Drought tolerance has also been incorporated in several other crops including wheat, which has performed well in initial field trials in Australia, with the best lines yielding 20% more than their conventional counterparts. **Drought tolerance is expected to have a major impact on more sustainable cropping systems worldwide, particularly in developing countries, where drought is more prevalent and severe than industrial countries.**

- **Helping mitigate climate change and reducing greenhouse gases**

  The important and urgent concerns about the environment have implications for biotech crops, which contribute to a reduction of greenhouse gases and help mitigate climate change in two principal ways. First, permanent savings in carbon dioxide (CO_2) emissions through reduced use of fossil-based fuels, associated with fewer insecticide and herbicide sprays; in 2011, this was an estimated saving of 1.9 billion kg of CO_2, equivalent to reducing the number of cars on the roads by 0.8 million. Secondly, additional savings from conservation tillage (need for less or no ploughing facilitated by herbicide tolerant biotech crops) for biotech food, feed and fiber crops, led to an additional soil carbon sequestration equivalent in 2011 to 21.1 billion kg of CO_2, or removing 9.4 million cars off the road. Thus in 2011, the combined permanent and additional savings through sequestration was equivalent to a saving of 23 billion kg of CO_2 or removing 10.2 million cars from the road (Brookes and Barfoot, 2013, Forthcoming).

Droughts, floods, and temperature changes are predicted to become more prevalent and more severe as we face the new challenges associated with climate change, and hence, there will be a **need for faster crop improvement programs to develop varieties and hybrids that are well adapted to more rapid changes in climatic conditions.** Several biotech crop tools, including tissue culture, diagnostics, genomics, molecular marker-assisted selection (MAS) and biotech crops can be used collectively for 'speeding the breeding' and help mitigate the effects of climate change. Biotech crops are already contributing to reducing CO_2 emissions by precluding the need for ploughing a significant portion of cropped land, conserving soil, and particularly moisture, and reducing pesticide spraying as well as sequestering CO_2.

In summary, collectively the above five thrusts have already demonstrated the capacity of biotech crops to contribute to sustainability in a significant manner and for mitigating the formidable challenges associated with climate change and global warming; and the potential for the future is enormous. Biotech crops can increase productivity and income significantly, and hence, can serve as an engine of rural economic growth that can contribute to the alleviation of poverty for the world's small and resource-poor farmers.

Beta Carotene in Golden Rice Sufficient to Control VAD

Women and children are the most vulnerable to vitamin A deficiency (VAD), the leading cause of childhood blindness and inability of the immune systems to combat disease. WHO reports in 2009 and 2012 that 190 to 250 million preschool children worldwide are still affected by VAD. A UNICEF report in 2010 showed that about 8.1 million children younger than 5 years old died in 2009 due to VAD. Studies showed that vitamin A supplementation could reduce all mortality in children younger than 5 years by 24-30%. This means that vitamin A availability for all children in undernourished settings could prevent 1.9 to 2.7 million child deaths annually.

After more than a decade, Golden Rice, a biotech genetically-modified rice that contains enhanced levels of beta carotene, is advancing towards the completion of its regulatory requirements in the Philippines and Bangladesh. In the Philippines, the International Rice Research Institute (IRRI) has successfully bred the Golden Rice traits into IR64 and Asian mega varieties including Philippine and Bangladeshi varieties, PSBRc82 and BRRI dhan 29, respectively. In the wet season of 2010 (September to December), IRRI completed one season of confined field tests of IR64-GR2 and received the certificate of completion from the National Committee on Biosafety of the Philippines. At the Philippine Rice Research Institute (PhilRice), confined field trials of advanced GR2 introgressed lines of PSBRc 82 were conducted in February to June 2011. In March 2012, four multilocational trials were started to evaluate the agronomic and product performance under Philippine field conditions; to produce grains and other plant materials that will be used for the various tests required to complete the biosafety data requirements; to obtain data for environmental biosafety assessment; and to produce grains that will be used for a nutritional study to be conducted if Golden Rice receives biosafety approval in the Philippines. Agronomic data have been collected and samples for compositional analysis are being tested in specific laboratories in the Philippines. Data analysis on various parameters is either ongoing or yet to be conducted based on data availability. As of this writing, the required second season multi locational trial has just been started in all four sites. It is expected that regulatory data required for the approval for Golden Rice commercialization will be completed by 2013. Another research effort by the PhilRice scientists is to develop the ‘3-in-1’ rice which incorporates resistance to tungro virus and bacterial blight disease. The researchers have identified promising lines which are being studied further (Antonio A. Alfonso, Personal Communications). In 2012, IRRI scientists have shared advanced breeding lines of Bangladeshi varieties containing the GR traits to the Bangladesh Rice Research Institute (BRRI). These lines have been evaluated under screenhouse conditions and confined field tests are planned (IRRI, 2012).

In 2011, IRRI, PhilRice and BRRI were joined by the Helen Keller International (HKI) institute to assess how the daily consumption of Golden Rice can help reduce vitamin A deficiency. HKI is a leading global health organization that advocates and conducts programs to reduce blindness and prevents malnutrition worldwide over the last 40 years. They have been partnering with governments and other health agencies to reach those most in need through various interventions.

Golden Rice has gone through all safety evaluations that have been appropriate and required at each stage of the project. The researchers are following international and national guidelines for food safety of genetically modified crops, which require assessment of the nutritional value of Golden Rice and potential toxicity and allergenicity of proteins from the new genes in it. The food safety-related studies that have been completed to date conclude that: 1) Beta carotene in food is a safe source of vitamin A. Beta carotene is found and consumed in may nutritious foods eaten around the world, including fruits and vegetables (Grune et al. 2010); 2) The beta carotene in Golden Rice is the same as the beta carotene that is found in other foods (Paine et al. 2005); and 3) The proteins from the new genes in Golden Rice do not show any toxic or allergenic properties (Goodman et al. 2006).

If Golden Rice is approved by national regulators, the Hellen Keller International will conduct a community-based study in the respective countries to determine if daily consumption of Golden Rice improves vitamin A status among adults. A delivery program will also be developed to ensure that Golden Rice could reach those most in need in vitamin A deficient communities. Golden Rice will be available to farmers and consumers only if it has been determined to be safe for humans, animals, and the environment and authorized for propagation and consumption by the appropriate regulatory authorities (IRRI, 2012).

A notable study to determine the conversion efficiency of beta carotene in Golden Rice was recently conducted in China. Tufts University researchers headed by Guangweng Tang (2012) studied 68 healthy Chinese children, ages 6-8 years old in Hunan province, China. The children were given beta-carotene either in the rice (as GM), in pure form in oil, or in spinach. The beta carotene they received contained isotopes enabling any vitamin A made from it to be distinguished from vitamin A that was already circulating in their blood. Results showed that spinach, GR, and beta carotene in oil capsule can all provide children with vitamin A nutrition. Furthermore, GR is as effective as the pure beta carotene in oil capsule, and both were more effective than spinach at contributing to the vitamin A intake of children. Analyses showed that it took 2.3 grams of beta-carotene derived from rice to make a single gram of vitamin A, slightly less compared to the use of oil which has conversion of 2 grams to 1. The study demonstrated that just 100 to 150 grams of the GM rice – about half the children's daily intake – provided 60% of the recommended daily intake of vitamin A. The paper concluded that, ***The Beta carotene in GR is as effective as pure Beta carotene in oil and better than that in spinach at providing vitamin A to children. A bowl of ~100 to 150g cooked GR (50 g dry weight) can provide ~60% of the Chinese Recommended Nutrient Intake of vitamin A for 6 – 8 old children.***

It is thus apparent that beta carotene enriched rice can overcome deaths due to VAD which numbers 1.9 to 2.7 million annually. This mortality range is higher than mortalities recorded for people with HIV/AIDS (1.8 million), tuberculosis (1.4 million) and malaria (0.7 million), however global expenditures for preventive and curative research to control VAD is much lower at US$15 million, compared to US$8.18 billion for the three diseases (http://www.globalhealthhub.org/2011/03/22/non-cummunicable-disease-and-the-rule-of-rescue/). Therefore, the low expenditure allotted for hunger and malnutrition still does not reflect the high priority given to it by the Copenhagen Consensus of 2012, 2008 and 2004 (http://www.copenhagenconsensus.com/Research/Index/Hunger.aspx). Research on biofortification field remains dramatically underfunded by the global community especially genetically modified biofortified crops. This could be the result of the relative newness of the field, suspicion on genetic engineering, food and environmental safety concerns, and bureaucratic delays. This leads to the reluctance of public, private and philanthropic sectors to support and fully engage in various endeavors for fear of controversy.

Once released, Golden Rice will be able to provide beta carotene fortified carbohydrate staple, providing more than a total of 2,006,869 million calories per day to people living in South Asia (with 1,130,648 million calories), Southeast Asia (660,979), Africa (125,124), Latin America (75,238), and Central Asia (14,880) – countries where most VAD occurs.

In an article, Ingo Potrykus (2010), co-inventor of Golden Rice concluded that biotech crops (GM) ***"could save millions from starvation and malnutrition, if they can be freed from excessive regulations."*** He reached this conclusion from his experience over the past 11 years chairing the Golden Rice Humanitarian project (http://www.goldenrice.org), and after a meeting hosted by the Pontifical Academy of Sciences at the Vatican in 2010 on biotech crops for food security in the context of development (Potrykus and Amman, 2010). Given that conventional breeding cannot increase Vitamin A, Golden Rice is possible only with biotech crops. Golden Rice was stalled for more than ten years because of unnecessary and unjustifiable delays, whilst millions were condemned to suffering. Potrykus concluded that the lag was entirely due to unjustified regulatory processes discriminating against biotech crops versus conventional crops. Hence, Potrykus holds the view that ***"the regulation of genetic engineering is responsible for the death and blindness of thousands of children and young mothers."*** He estimated that it generally takes about ten times more money and ten years longer to bring a biotech crop to market compared to a conventional crop, and de-facto, because of the higher costs, precludes the participation of public research institutions in the development of biotech crops. Biotech crops have enormous potential to alleviate poverty and hunger and contribute to food security in the developing countries of the world.

With all these potential benefits in Golden Rice, still a number of sceptics such as Greenpeace, are conducting anti-Golden Rice campaign which could delay the approval and commercialization process. Writer Margaret Wente (The Globe and Mail, 13 September 2012) expressed her sentiments in her article on "Greenpeace's Golden Rice stand should appall us all". She exposed how Greenpeace and Chinese bloggers negatively played up the Golden Rice trials in China. She said, ***"Are Greenpeace and its allies effectively allowing millions of children to go blind or die when there's a safe solution? The rest of us should be appalled."***

Dr. Patrick Moore, co-founder of Greenpeace in his keynote address at the Manitoba Special Crops Symposium in Winnipeg in February 2012 expressed his regrets in the slow release of the Golden Rice (Portage Online, 10 February 2012). ***"Other GM rice varieties are able to eliminate micronutrient deficiency in the rice eating countries, which afflicts hundreds of million people, and actually causes between a quarter and half a million children to go blind and die young each year because of vitamin A deficiency because there is no beta carotene in rice,"*** says Moore. ***"We can put beta carotene in rice through genetic modification, but Greenpeace has blocked this."*** He added, that this action is a crime against humanity because they are preventing the curing of people who are dying by the hundreds of thousands a year due to vitamin A deficiency. He also mentioned the positive effect of GM soybeans that produce omega-3 fatty acids not only for humans but also for the aquaculture industry whose fatty acid source is the limited and costly fishmeal.

In 10 September 2012, Dr. Patrick Moore once again criticized Greenpeace in an article published online in climatedepot.com (Climate Depot, 10 September 2012). ***"It is clear by the facts that Greenpeace is guilty of crimes against humanity as defined by the International Criminal Court. They claim that 'Golden Rice is a failure' while they are the ones responsible for preventing the cure that is so desperately needed by millions of civilians. The fact that Greenpeace perpetuate lies about Golden Rice while at the same time doing nothing to solve the problem themselves constitutes gross negligence on top of the crime against humanity."***

In summary, future prospects up to the MDG year of 2015 and beyond, look encouraging: an increase in the number of developing countries planting biotech crops, led by Asia and there is cautious optimism that Africa will be well-represented: the first biotech based drought tolerant maize to be planted in the US in 2013 is a key strategic development with same technology donated by Monsanto and BASF to Africa, expected to be released in Africa around 2017 or later; the first stacked soybean with herbicide tolerance and insect resistance to be planted in Brazil in 2013; Golden Rice planned for release in the Philippines in 2013/2014; biotech maize in China with a potential of up to ~30 million hectares and thereafter Bt rice which has an enormous potential to benefit up to 1 billion poor people in rice households in Asia alone. Biotech crops, whilst not a panacea, have the potential to make a substantial contribution to the 2015 MDG goal of cutting poverty in half, by optimizing crop productivity, which can be expedited by public-private sector partnerships, such as the WEMA project, supported in poor developing countries by the new generation of philanthropic foundations, such as the Gates and Buffet foundations.

CLOSING COMMENTS

In May 2011, the UN Population Division published its projections of global population for the end of this century in 2100, (UN Pop Div, 2011) when the global population could reach 10.1 billion, almost 50% more than today's 7 billion. The most remarkable change is not the increase of 3 billion globally, but the demographic shift that will take place due to the enormous growth in high-fertility developing countries, particularly in Africa. The population of sub Sahara Africa could increase from 1 billion today (15% of global) to 3.6 billion in 2100 which is 35% of global population – that is a startling statement given that Africa cannot even feed its 1 billion people today which is only one-third of its population of 3.6 billion in 2100. This high population growth in Africa is driven by a group of high-fertility countries, such as Nigeria whose population is expected to increase more than five-fold from 135 million today to 730 million; similarly Kenya whose population is expected to quadruple from 40 million today to 160 million by 2100. There are also some high-fertility countries in Asia such as the Philippines, expected to double from 85 million today to 179 million in 2011. In a landmark event, well before 2100, India will have replaced China as the most populous country in the world with 1.5 billion. India will be followed by China at 940 million, and Nigeria will move up from #9 today to #3 in 2100 with 730 million. Of the top 20 most populous countries today, only 3 are from Africa but this will triple to 9 in 2100 – they include Tanzania at 316 million, Democratic Republic of Congo at 212 million, Uganda at 171 million, Ethiopia at 150 million, Zambia 140 million, Niger139 million, Malawi 130 million, and Sudan at 128 million. Whilst the population of most countries will decline between now and 2100, the high-fertility countries will more than compensate for the decline in population in most industrial countries. The USA is an exception, expected to grow by about 50% from 300 million today to 478 million in 2100. The 50% increase in global population between now and 2100, plus a change in life style (creation of an enormous new middle class) and consumption of more meat presents a formidable challenge to increase crop production (the main source of food and animal feed) to achieve food, feed and fiber security in 2100.

The most recent 2012 FAO Report on Food Insecurity in the world and the resulting impact on poverty and malnutrition (FAO 2012, Food Insecurity in the World) concluded that 870 million people suffer from hunger and malnutrition today. Whereas this is an improvement on earlier reports, most of the progress was made <u>before</u> the food price hikes of 2008 after which progress has stagnated. This means that the goal of halving poverty and malnutrition is within reach, only if appropriate action is taken to reverse the slow down in progress since 2008.

Importantly, the report concludes that, "***Agricultural growth is particularly effective in reducing hunger and malnutrition. Most of the extreme poor depend on agriculture and related activities for a significant part of their livelihoods. Agricultural growth involving smallholders, especially women, will be most effective in reducing extreme poverty and hunger when it increases returns to labor and generates employment for the poor.***"

The three regions that suffer most from malnutrition and hunger are:
- Southern Asia (304 million representing ~35% of the world's poor);
- Sub Sahara Africa (224 million equivalent to ~25% of the world's poor); and
- Eastern Asia (167 million or ~20% of the world's poor).

Collectively these three regions total 705 million poor, hungry and malnourished people, equivalent to just over 80% of the world's 870 million hungry and malnourished poor people – these people cannot "live" because they can barely survive and cannot afford adequate food for their sustenance – equally devastating, they have also suffered the loss of their dignity as human beings.

The 2011 edition of FAO's published report on "The State of Food Insecurity in the World" (FAO, 2011), focused on the impact of food price volatility and high food prices. The Report predicts that both price and volatility are likely to continue to increase in the future. The G20 Finance Ministers and Central Bank Governors have become engaged in finding cost-effective ways to reduce price volatility and mitigate its effects when they do occur. The food and economic crises of 2006 to 2008 are challenging efforts to achieve the Millennium Development Goal of reducing, by half, the proportion of people who suffer from hunger.

In the next fifty years, the world will consume twice as much food as the world has consumed since the beginning of agriculture 10,000 years ago – a profound and consequential statement that deserves a reasoned and urgent response from society. However, regrettably, the vast majority of global society is disinterested and completely unaware of the formidable challenge of feeding the world of tomorrow. Similarly, society is unaware of the potential contribution of technology, particularly the role of the new innovative bio-technologies, such as biotech crops, that already successfully occupy 170 million hectares equivalent to more than 10% of global arable land.

Given this lack of awareness about the challenge and the role of the new innovative crop biotechnologies, ISAAA initiated a program more than 10 years ago to freely share science-based knowledge about biotech crops with global society, whilst respecting the right of society to make independent informed decisions about the role of the new technologies. Two initiatives have been particularly successful, the first is ISAAA's Annual Brief on the global status of biotech crops and their impact.

Messages from ISAAA Brief 43 for 2011 are estimated to have resulted in 3 billion impressions in 74 countries in 58 languages – the publication stimulated 2,529 multi-media reports and the Brief is the most widely quoted publication on biotech crops globally. The second initiative is a weekly email which summarizes the major developments in biotech crops that are of particular interest to developing countries. The free weekly e-newsletter, named Crop Biotech Update (CBU) is distributed to subscribers in 200 countries and translations are available in more than 10 of the major languages of the world, including Chinese, Arabic, Bahasa Indonesia, Japanese, Spanish, Portuguese and French.

ISAAA was founded more than 20 years ago to establish creative new partnerships to facilitate the transfer of crop biotech applications from the industrial countries, particularly the private sector, for the benefit of small resource-poor farmers in the developing countries who represent a significant segment of the poorest people in the world. Subsequent to the founding of ISAAA in 1990 it became evident that the lack of awareness by society of the potential of the new innovative biotech crops was a major constraint to acceptance, exacerbated by well-resourced and extensive mis-information campaigns about biotech crops by opponents of the technology.

The international community involved with biotech crops from the public and private sectors globally, as well as the political, donor scientific communities and partner developing countries have not taken full advantage of the MDG anniversary in 2015, to make global society aware of the gravity and urgency of the impending global food crisis. If global food insecurity is to be averted, and there is no other option, urgent action is required now to make society aware of the humanitarian consequences of inaction, and the important contribution that innovative technology, including biotech crops, can make to food security and the imperative of “the right to food and the alleviation of poverty”. The innovative partnership that is proposed would engage all points of the compass, North, South, East and West, embracing both public and private sectors, in a collective effort by committed individuals and institutions to optimize the contribution of biotech crops to productivity, whilst using less resources, and helping to alleviate poverty by 2015 and beyond. There is no better way to contribute to the MDG goal of alleviating poverty, hunger and malnutrition, by 50% by 2015, which coincidentally marks the end of the second decade of commercialization of biotech crops, than to pledge, as individual global citizens, to contribute to food security, which will also contribute to a more peaceful world. Norman Borlaug, the Nobel Peace Laureate of 1970, who saved one billion people from hunger, opined that ***“you cannot build peace on an empty stomachs”*** – and he was right – the right to food is imperative. Food insecurity was one of the principal factors that ignited the Arab Spring – poor people could not afford food. The poor are not only denied access to food but also suffer indignity which should not be tolerated in a just society. Whereas biotech crops should not be viewed as a panacea, they have already made a credible contribution to food security and the potential for the future is enormous.

Acknowledgments

The provision of data on global adoption of commercialized biotech crops by a legion of colleagues, too numerous to name, from the public and private sectors in industrial and developing countries is much appreciated. Without their collaboration, this publication would not be possible. A very special thanks to my wife Glenys James who, as always, has given her time freely to ISAAA and diligently assisted with the preparation of the manuscript, and gave me encouragement and support. It is a pleasure to thank Dr. Randy A. Hautea, Global Coordinator and Director of the ISAAA SEAsiaCenter and his staff, for always providing excellent and expeditious services for formatting and proofreading the manuscript. Particular thanks to Dr. Rhodora R. Aldemita for coordinating, verifying, and editing the entire document, and for overseeing and expediting the preparation of the manuscript for publication; to Mr. Bhagirath Choudhary for preparing three country chapters; Dr. Margaret Karembu for contributing three country chapters; Dr. Anderson Gomez for preparing one country chapter; Dr. Renando O. Solis for compiling data on GMO regulatory approvals; Clement Dionglay for formatting all texts, tables and figures; and for the assistance of Dr. Mariechel J. Navarro, Jenny A. Panopio, Panfilo G. De Guzman, Eric John F. Azucena, Fely H. Almasan, Kristine L. Natividad, Teresita F. Victoria, Mario DC Generoso, Ervin M. Naval and Kaymart A. Guimutao. The author takes full responsibility for the views expressed in this publication and for any errors of omission or misinterpretation.

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Appendix 1

Global Crop Protection Market

Table 1. Global Crop Protection Market, 2011

US$M	Herbicides	Inscticides	Fungicides	Others	Biotech	Total
North America	6,503	1,825	1,344	490	10,226	19,939
West Europe	3,606	1,323	3,249	645	28	8,851
East Europe	882	462	442	102	5	1,892
Japan	1,250	1,109	884	115	0	3,358
Australia	1,070	419	264	79	33	1,866
Industrial Countries	**12,862**	**5,138**	**6,183**	**1,431**	**10,292**	**35,906**
Latin America	4,702	2,988	3,139	459	2,017	13,305
Rest of Far East	1,781	2,235	1,892	194	393	6,495
Rest of World	794	1,594	688	100	648	3,824
Developing Countries	**7,278**	**6,817**	**5,719**	**752**	**3,058**	**23,625**
Total	**20,139**	**11,956**	**11,902**	**2,184**	**13,350**	**59,531**

Source: Cropnosis, 2012 (Personal communication)

Appendix 2

Useful Tables and Charts on the International Seed Trade

Reproduced with the Permission of the
International Seed Federation (ISF)

Table 1. Seed Exports (FOB) of Selected Countries, 2011 (with over 100 Million US$ Market)*

Country	Field Crops	Vegetable Crops	Total
France	1,232	366	1,616
Netherlands	256	1,146	1,476
USA	813	507	1,394
Germany	638	73	745
Hungary	374	18	392
Chile	218	131	380
Italy	198	118	319
Denmark	232	46	280
Canada	256	3	259
Romania	214	0	214
Belgium	203	4	209
China	75	105	195
Mexico	175	19	194
Argentina	170	17	187
Brazil	161	11	172
Spain	99	64	163
Others	1,065	681	1,792
Total	**6,379**	**3,909**	**9,987**

Table 2. Seed Imports (FOB) of Selected Countries, 2011 (with over 100 Million US$ Market)**

Country	Field Crops	Vegetable Crops	Total
USA	523	318	908
Germany	595	97	714
France	522	150	683
Netherlands	250	330	628
Italy	231	177	417
Russian Federation	312	70	387
Spain	185	195	384
Mexico	123	215	338
Ukraine	298	30	328
United Kingdom	209	83	308
China	113	114	237
Canada	128	78	221
Japan	93	94	206
Belgium	155	29	187
Poland	119	45	166
Turkey	60	104	166
Romania	128	17	147
Hungary	116	20	137
Brazil	46	64	113
Others	1,475	922	3,423
Total	**5,681**	**3,152**	**9,098**

Source: International Seed Federation, 2011
*http://www.worldseed.org/cms/medias/file/ResourceCenter/SeedStatistics/SeedExports/Seed_Exports_2011.pdf
**http://www.worldseed.org/cms/medias/file/ResourceCenter/SeedStatistics/SeedImports/Seed_Imports_2011.pdf

Appendix 3

Deployment of Approved Bt Cotton Events/Hybrids/Variety by Companies/Institutions in India

Table 1. Deployment of Approved Bt Cotton Events/Hybrids/Variety by Companies/Institutions in India, 2002 to 2012

Event	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
NORTH ZONE Haryana Punjab Rajasthan				6 Hybrids 1 Event 3 Companies	14 Hybrids 3 Events 6 Companies	32 Hybrids 4 Events 14 Companies	62 Hybrids 4 Events 15 Companies	164 Hybrids 5 Events 26 Companies	271 Hybrids 5 Events 31 Companies	279 Hybrids 5 Events 34 Companies	327 Hybrids 5 Events 39 Companies
CENTRAL ZONE Gujarat Madhya Pradesh Maharashtra	3 Hybrids	3 Hybrids	4 Hybrids	12 hybrids 1 Event 4 Companies	36 Hybrids 4 Events 15 Companies	84 Hybrids 4 Events 23 Companies	148 Hybrids 4 Events 27 Companies	296 Hybrids 6 Events 35 Companies	459 Hybrids 6 Events 35 Companies	549 Hybrids 6 Events 40 Companies	655 Hybrids 6 Events 44 Companies
SOUTH ZONE Andhra Pradesh Karnataka Tamil Nadu	3 Hybrids	3 Hybrids	4 Hybrids	9 Hybrids 1 Event 3 Companies	31 hybrids 4 Events 13 Companies	70 Hybrids 4 Events 22 Companies	149 Hybrids 4 Events 27 Companies	294 Hybrids 6 Events 35 Companies	444 Hybrids 6 Events 35 Companies	488 Hybrids 6 Events 37 Companies	610 Hybrids 6 Events 43 Companies
Summary											
Total no. of hybrids	3	3	4	20	62	131	274	522*	780	884*	1,097*
Total no. of events	1	1	1	1	4	4	4	6	6	6	6
Total no. of companies	1	1	1	3	15	24	30	35	35	40	44

* Some of the 1,097 hybrids are being grown in multiple regions regions (excluding a hybrid and a variety of Event BNLA-601 which are discontinued since 2010)
Source: Compiled by ISAAA, 2012.

Appendix 4

Listing of Events, Bt Cotton Variety and Hybrids in India

Table 1. Listing of events, Bt cotton variety and hybrids in India, 2012

Zone	BG-I Hybrids	BG-II Hybrids	GFM/Event-I/MLS-9124/BNLA-601
North Zone (327 Hybrids 5 Events, 39 Companies)	ABCH 223 Bt, ABCH 224 Bt, ABCH 225Bt, ABCH 226Bt, ABCH 227Bt, ABCH 228 Bt, ABCH 229Bt, ABCH 230Bt, ABCH 231Bt, ABCH-232Bt, ABCH-235Bt, ABCH-3083Bt, ABCH-3483 Bt, ABCH-1857 Bt, ABCH-172 Bt, ABCH-173 Bt, ABCH-174 Bt, ABCH-177 Bt, ABCH-178 Bt, Ankur 3028 Bt, Ankur 8120 Bt, Ankur-651, Ankur-2226, Ankur-2534, GK-206, IT-905, Jai Bt, KDCHH-553 BGI, KSCH-201 Bt, KSCH-204 Bt, KDCHH-507 BG-I, KDCHH-9810, MRC-6025, MRC-6029, MRC-6301, MRC-6304, NAMCOT-402, NCS-138, NCS-913, NCS-950, NCS-901 Bt, NCS-902 Bt, NCS-903 Bt, NCS-904 Bt, NCS-905 Bt, Ole, SP504B1 BGI, NCS 1915 Bt , NCS 1916 Bt, PCH-1414 Bt, PRCH-721Bt, PRCH-722 Bt, PCH 401 Bt, PCH 402 Bt, PCH 403 Bt, PCH-406 Bt, RCH-134, RCH-308, RCH-314, RCH-317, SDS-9, SDS-1368, Shakti-9 Bt, Sigma, SP 7007 B1, VBCH-1006 BG, VBCH-1008 BG, VICH-11 BG, 6317 Bt, 6488 Bt	ABCH 243 Bt, ABCH 244 Bt, ABCH 245Bt, ABCH 246Bt, ABCH 247Bt, ABCH 248 Bt, ABCH 251Bt, ABCH 252Bt, ABCH 254Bt, ABCH-256 Bt, ABCH-1299 Bt (BG-II), ABCH-2099 Bt (BG-II), ABCH-4899 Bt (BG-II), ABCH-7399 Bt (BG-II), ABCH-143 Bt (BG-II), ABCH-146 Bt (BG-II), ABCH-181 Bt (BG-II), ABCH-182 Bt (BG-II), ABCH-191 Bt (BG-II), ABCH-192 Bt (BG-II), ACH-155-2, ACH177-2, ACH133-2, ACH 33-2, ACHH 1 BG-II, ACHH 2 BG-II, ANKUR 3224 BGII, ANKUR 3244 BGII, ANKUR 3228 BGII, Ankur 3028 BG-II, ANKUR-5642, ANKUR-8120, DPC 3085 BGII, D-29 BG-II, DPC 3083 BG-II, DPC 3081 BG-II, GBCH-85 BG-II (KUBER BG-II), GBCH-95 BG-II (VARDAN BGII), GK-228 BGII,GK-239 BGII, GK-212, GOLDSTAR BGII, Jai BG-II, Jassi, JKCH 0109 BGII, JK TARZAN BG-II, JKCH 1050 BG-II, JKCH 1947 BG-II, KCH-36 BG-II, KCH999 BG-II, KCHH-2101 BG-II, KCH-14K59 BGII, KCH-15K39 BGII, KCH-100 BG-II, KCH-172 BG-II, KCH-189 BG-II, KCH-311 BG-II, KCH-707 Bt, KDCHH-541 BGII, KDCHH-441, KCH-100BGII, KCH-172BGII, KCH-189BGII, KCH-311BGII, KDCHH-516 BGII, KDCHH-621 BGII , KDCHH-641 BGII, KDCHH-9810 BGII, KSCH-207 Bt, KSCH-209 BG-II, KSCH-210 BG-II, KSCH-211 BG-II, KSCH-213 BG-II, KSCH-215 BG-II, KSCH-218 BG-II, MH 5302 BG-II, MH 5304 BG-II, MRC-7301 BGII, MRC-7347 BGII, MRC-7351 BGII, MRC-7361 BG II, MRC-7365 BG-II, MRC-7017, MRC-7031, MRC-7041, MRC-7045, NCS 9002Bt2 , NCS 9011 Bt2, NAMCOT-616 BGII, NAMCOT-617 BGII, NCS 9012 Bt2, NCS 9013 Bt2 , NCS 9024 Bt2, NCS-855 Bt2, NCS-856 Bt2, NCS-857 Bt2, NCS-858 Bt2, NCS-145 (Bunny), NCS 459 BGII, NCS 950 BGII, NCS 4455 BGII, NCS 189 BGII, NCS 2223 BG II, NCS 495 BGII, NCS 558 BGII, NSPL 252 BG II, NSPL 531 BG II, NSPL 2223BGII, PCH-9602 Bt2, PCH-9604 Bt2, PCH-9605 Bt2, PCH- 9609 Bt2, PCH-9611 Bt2, PCH-876 Bt2, PCH-877 Bt2, PCH-878 Bt2, PCH-879 Bt2, PCH 225 BGII, PCH 360 BGII, PCH 5678 BGII, PRCH 732 BGII, PRCH 711 BGII, PRCH 7776 BGII, PRCH 7799 BGII, RACHH-1811 BG-II, RCH650 BGII , RCH 653 BGII, RCH-602 BGII, RCH-605 BGII, RCH-314 BGII, RCH-134, RCH773 BG-II, RCH776 BG-II, PRCH-708 Bt2, PRCH-302, PRCH-333, SDS-27 BG II, SDS-6003 BGII, SDS-234 BGII, SDS-9, SDS-36, SOLAR-56 BG-II, SOLAR-64 BG-II, SOLAR-65 BG-II, SOLAR-72 BG II, SOLAR-75 BG-II, SOLAR-76 BG-II, SOLAR-77 BG-II, Shakthi 9 BGII, SP7007B2, SP7114B2 BGII, SP504B2 BGII, SRCH-666 BG-II, SRCH-888 BG-II, SRCH-999 BG-II, SO7H878 BGII, SP1169B2, 54 SS 33 BG-II, 45 SS 33 BG-II, 51 SS 33 BG-II,	MH 5270 Bt, NBC-51, Navkar-5 Bt, NCEH-6R, NCEH-26 Bt, NCEH-31 Bt, NCH-1005 Bt, NCH-1085 Bt, NCH-1163 Bt, NCH-1177 Bt, NCEH-51, NCEH-145, SBCH-278 Bt, SBCH-290Bt,YRCH-18Bt, UPLHH- 12 Bt, UPLHH-271 Bt, UPLHH- 342 Bt, UPLHH- 350 Bt, ZCH-193 Bt, UPLHH-1, YRCH-22Bt,YRCH-36Bt, YRCH-40Bt, ***JKCH-109 Bt, JKCH-104 Bt, JKCH-1950 Bt, JKCH-99 Bt, JKCH-1145 Bt, JKCH-1923 Bt, JKCH-1945 Bt, JKCH-1947, JK-1050, JKCH-226 Bt,*** **BNBt (Variety)***

Table 1. Listing of events, Bt cotton variety and hybrids in India, 2012

Zone	BG-I Hybrids	BG-II Hybrids	GFM/Event-I/MLS-9124/BNLA-601
		SS 333 BG-II, SS 119 BG-II, SP 7010B2, SWCH-4735 BGII, SWCH-4744 BGII, SWCH-4748 BGII, SWCH-4750 BGII, SWCH-4755 BGII, SWCH- 4757 BGII, SWCH-4768 BGII, SWCH-4770 BGII, SWCH-4707 BG-II, SWCH-4711 BG-II, SWCH-2 BG-II, SWCH-4704 BG-II, SWCH-4713 BG-II, Super-721BGII, Super-931BGII, Super -965BGII,Super-971BGII,Super-5BGII, Super-511BGII, Super -544BGII, TULASI-9 BGII, TULASI 118 BGII, TULASI 252BGII,TULASI 135BGII, TULASI 171BGII, Tulasi-162 BG II, Tulasi-225 BG-II, Tulasi-4, Tulasi-45, VBCH-1532 BGII, VBCH-1533BGII, VBCH-1534BGII,VBCH-1544BGII, VBCH 1515 BGII, VBCH 1516 BGII,VBCH 1517 BGII, VBCH 1518 BGII, VBCH-1501, VBCH-1504, VICH-307 BG-II, VICH-308 BG-II, VICH-309 BG-II, VICH-310 BG-II, VICH-9, VICH-11, Western Nirogi-151 BG-II, 569, 6488- 2, 2510-2, 2113-2, 841 2(BGII), 846-2(BGII), 311-2 (BGII), 6165-2 BG-II, 6317-2 BG-II, 6539-2 BG-II, ZCH-1101 BGII, ZCH-1102 BGII, ZCH-904 BG-II	
Central Zone (655 Hybrids 6 Events, 44 Companies)	ABCH 223Bt, ABCH 224Bt, ABCH 225Bt, ABCH 226Bt, ABCH 227Bt, ABCH 228Bt, ABCH 229Bt, ABCH 230Bt, ABCH 231Bt, ABCH 236Bt, ABCH 237Bt, ABCH-3083 Bt, ABCH-3483 Bt, ABCH-1857 Bt, ABCH-172 Bt, ABCH-173 Bt, ABCH-174 Bt, ABCH-177 Bt, ABCH-178 Bt, ABCH-1165, ABCH-1220, ACH 33-1, ACH 155-1, ACH-177-1, Akka, Ankur 3042 Bt, Ankur-9, Ankur-651, Ankur-3032 Bt, Ankur HxB-1950 Bt, Brahma, Dyna, GK-204, GK-205, Jai Bt, KCH-135, KCH-707, KCHB-2250 BG-I, KDCHB-407 BG-I, KDCHH-507 BG-I, KDCHH-786, DCHH-9632, KDCHH-9810, KDCHH-9821, KDCHH-553 BGI, KSCH 201 BGI, KSCH 204 BGI, Mahasangram BG, MECH-12, MECH-162, MECH-184, MRC-6301, MRC 6304 Bt, NCS-906 Bt, NCS-907 Bt, NCS-908 Bt, NCS-909 Bt, NCS-910 Bt, NCS-138, NCS-145 (Bunny), NCS-207 (Mallika), NCS-913, NCS-929, NCS- 950, NCS-954, NCS-955, NCS 1911 BG-I, NCS 1914 BG-I,	ABCH-1299 Bt (BG-II), ABCH-2099 Bt (BG-II), ABCH-4899 Bt (BG-II), ABCH-7399 Bt (BG-II), ABCH-1020 Bt (BG-II), ABCH-143 Bt (BG-II), ABCH-146 Bt (BG-II), ABCH-181 Bt (BG-II), ABCH-182 Bt (BG-II), ABCH-191 Bt (BG-II), ABCH-192 Bt (BG-II), ABCH 243Bt ,ABCH 244Bt , ABCH 245Bt, ABCH 246Bt, ABCH 247Bt , ABCH 248Bt, ABCH 252Bt, ABCH 254Bt, ABCH 256Bt, ABCH 240Bt, ABCH 241Bt, ACH-5 BGII, ACH-6 BGII, Paramveer (ACH-12-2 BGII), ACH-52-2 BGII, ACH-111-2, ACH-177-2, ACH 104-2 (Ajeet 104) BG-II, ACHB 901-2 (Ajeet 901) BG-II, ACH 133-2 (Ajeet133) BG-II, Ajeet-11-2, Ajeet-155-2, Ajeet 199 BGII, Akka, Amar-1065 Bt, ANKUR 3224 BGII, ANKUR 3244 BGII, ANKUR 3228 BGII , ANKUR 5642 BGII, ANKUR 3066 BGII, Ankur-3028 BG-II, Ankur-3034 BG II, Ankur- 216 BG II, Ankur- 257 BG II , Ankur- 3070 BG II, Ankur HB 2104 BG-II, Ankur 651 BGII, ATAL BG-II, BAT HH 201 BGII, BAT HH 210 BGII, BAT HH 214 BGII, BATHH-205 BG-II, BATHH-218 BG-II, Brahma BGII, CTH 2 BGII, DBH-2 BG-II, DBH-1 BG-II, DPC 9066 BGII, DPC 7064 BGII, DPC 7065 BGII, DPC 9062 BG-II, DPC 9083 BG-II, DPIR 080001 BG-II, D-29 BG-II, EGCH 1447 BGII, GBCH-85 BG-II (KUBER BG-II), GBCH-95 BG-II (VARDAN BGII), GBCH-90 BG-II, GBCH-8888 BG-II, GBCH-9999 BG-II, G.COT.Hy-6 BG-II, G.COT.Hy-8 BG-II, GK 220 BGII, GK 249 BGII, GK-228 BGII, GK-238 BGII,	ACH-1575 Bt, ACH 1050 Bt, ACH 1151 Bt, ACH 1171 Bt, ACH-1019, Dhruv Bt, Kashinath, GBCH-07 Bt, GBCH-09 Bt, GBCH-01, MH 5225 Bt, MH 5234 Bt,MH 5243 Bt, MH 5274 Bt, Monsoon Bt, Navkar-5, NCEH-29, NCEH-24, NCEH-210, NCEH-2R, NCEH-3R, NCEH-21, NCEH-23, NCEH-14, NCEH-34 Bt, SBCH-310Bt(Gazab Bt), SBCH-286 Bt (Raka Bt), SBCH- 311Bt, SSB-71Bt, SSB-72Bt, TPHCN07-015 Bt, TPHCN07-005 Bt, TPHCN07-009 Bt, UPLHH-271 Bt, UPLHH-17 Bt, UPLHH-12 Bt, UPLHH-189 Bt, UPLHH-352 Bt, UPLHH-13 Bt,UPLHH-1Bt, UPLHH-10 Bt, UPLHH-2Bt, YRCH-18Bt,YRCH-22Bt,YRCH-36Bt,YRCH-40Bt, YRCH-4 Bt, YRCH-9 Bt, YRCH-13 Bt, YRCH-31 Bt, YRCH-45 Bt, YRCH-54 Bt, ZCH-50005, ZCH-50072 Bt, YRCH 18 Bt, YRCH 22 Bt, YRCH 36 Bt, YRCH 40 Bt, ***JK INDRA VAJRA Bt, JK SUPER VARUN Bt, JK SHIKHAR Bt (JKCH-1305 Bt), JK AGNI Bt (JKCH-2022 Bt), JK RUBY Bt (JKCH-2246 Bt), JK-Chamundi Bt, JK-Gowri Bt,***

Table 1. Listing of events, Bt cotton variety and hybrids in India, 2012

Zone	BG-I Hybrids	BG-II Hybrids	GFM/Event-I/MLS-9124/BNLA-601
	NCHB-991, NCHB-992, NPH-2171, NSPL-36, NSPL-405, NSPL-999, PCH-404 Bt, PCH-405 Bt, PCH-407 Bt, PCH-408 Bt, PCH-409 Bt, PCH-115, PCH-207 (PCH-205), PCH-923, PCH-930, PCH 1412 BG-I, PCH 1411BG-I, PCH 2270 BG-I , PRCH-724Bt, PRCH-725 Bt, PRCHB- 405 BG-I, PRCH-102, PRCH-31, Rudra, RCH-134 Bt, RCH-2, RCH-118, RCH-138, RCH-144, RCH-377, RCH-386, RCH-395 Bt, Sarju-BG, Sigma, SP 1136 B1, SP-499, SP-503, SP-504 (Dhanno), SP-904, SP-923, SWCH-4428 Bt, SWCH-4531 Bt, SWCH-4314 Bt, Tulasi-4, Tulasi-5 Bt, Tulasi-9, Tulasi-117, VBCHB-1201BG, VBCHB-1202BG, VBCHB-1203BG, VBCH-101, VBCH-1006,VBCH-1009, VBCH-1010, VBCH-1016, VBCH-1017,VCH-111, VICH-5, VICH-9, VICH-15, 322 Bt, 110 Bt, 6188 Bt, 563 Bt , 311 Bt	GK-244 BGII, GK-218 BGII, GK-221 BGII , GK-224 BGII , GK-231 BGII , GK-235 BGII , GK-205, Jai BG-II, JKCH 99 DOUBLE Bt (JKCH99 BG II) , JKCH 2245 DOUBLE Bt (JKCH 2245 BGII), JK DURGA DOUBLE Bt (JKDURGABGII), JKCH 8665 BG-II, JKCH 0034 BG-II, JKCH 8836 BG-II, INDRA VAJRA DOUBLE Bt (INDRA VAJRA BGII), IAHH-2 BG-II, IAHH 178 BG- II, KCH 100 BGII, KCH-172BGII, KCH-189BGII, KCH 311BGII, KCH-14K59 BG-II, KCH-15K39 BG-II, KCH-36 BG-II, KCH-999 BGII, KCH-707, KCH-135, KCH-108 BG-II, KCH-111 BG-II, KCH-144 BG-II, KCH-711 BG-II, KCHH-2101 BG-II, KCHH-1049 BG-II, KCHH-2739 BG-II, KCHH-2108 BG-II, KDCHH-9810 BGII, KDCHH-641 BGII, KDCHH-541 BGII, KDCHB-407 BG-II, KDCHH-441, KDCHH-621, KDCHH-9632, KCHH-8152 BGII, KCHH-932 BGII, KCHH-904 BGII, KDCHH 02 BGII, KDCHH 202 BGII, KDCHH 065 BGII, KDCHH 722 BGII, KDCHH 532 BGII, KDCHH 810 BG-II, KDCHH 9632 BG-II, KSCH 212 BGII, KSCH 207 BG II, KSCH-251 BG-II, KSCH-211 BG-II, KSCH-213 BG-II, KSCH-216 BG-II, KSCH-208 BG-II, KSCH-220 BG-II, KSCH-221 BG-II, Krishna BGII, MH 5342 BG-II, MH 5351 BG-II, MH 5343 BG-II, MH 5361 BG-II , MH 5362 BG-II, MH 5363 BG-II, MLBCH6 BGII, MLCH-317, MRC-7373 BG II, MRC-7383 BGII, MRC-7301, MRC-7326, MRC-7347, MRC-7351, MRC- 7918, MRC-7361 BGII, MRC-7375 BGII, MRC-7377 BGII, MRC-7385BGII, MRC-7387 BGII, MRC 7017 Plus BGII, MRC 7351 GOLD BG-II, MRC 6918 XXL BGII, MRC 7371 BG-II, MRC 7388 BG-II, MRC 7391 BG-II, Mahasangram BGII, NAMCOT 621 BGII, NAMCOT 627 BGII, NCS 9014Bt2 , NAMCOT 614 BGII, NAMCOT 615 BGII, NAMCOT 603 BGII, NAMCOT 605 BGII, Namcot 803 BG-II, NCS 9015 Bt2, NCS 9025 Bt2, NCS 9028 Bt2, NCS 9030 Bt2, NCS 950Bt2, NCS 954 Bt2, NCS 955 Bt2, NCS 929 Bt2, NCS 138 Bt2, NCS 856Bt2, NCS 858Bt2, NCS 865 Bt2, NCS 866Bt2, NCS-859 Bt2, NCS-860 Bt2, NCS-861 Bt2, NCS-862Bt2, NCS-853Bt2, NCS-145 Bt 2, NCS-207 (Mallika), NCS-854 Bt 2, NCS 459 BGII, NCS 852 BGII, NCS 855 BGII, NCS 857 BGII, NCS 864 Bt2 BGII, NCS 867 BGII, NCS 908 BGII, NCS 909 BGII, NCS 913 BGII, NCS 1122 BGII, NCS 2244 BGII, NCS 8899 BGII, NCS 9011 BGII, NCS 9012 BGII, NCS 9024 BGII, NCCH-0004 BG-II, NCCH-0006 BG-II, NCCH-0002 BG-II, NCS 245 BG-II, NCS 2434 BG-II, NCS 1012 BG-II, NCS 927 BG-II, NCS 1111 BG-II, NCS 6566 BG-II, NCS 3456 BG-II, NCS 9999 BG-II, NCS 1134 BG-II, NCS 589 BG-II, NCHB-9901 Bt2,	***JKCH-2245 Bt, JKCHB-229 Bt, JK-Ishwar (JKCH-634 Bt), JKCH-99, JKCH-226, JKCH-666, JK-Durga Bt, JK- Indra Bt, JK-Varuna, PCH-66Bt, PCH-55Bt, PCH- 44Bt, PCH-22Bt, PCH-99 Bt, PCH-77 Bt, PRCH-712 Bt, PRCH-713 Bt, PRCH-714 Bt, PRCH-715 Bt,*** **MH-5125Bt, MH-5174Bt, BN Bt (Variety)***

Table 1. Listing of events, Bt cotton variety and hybrids in India, 2012

Zone	BG-I Hybrids	BG-II Hybrids	GFM/Event-I/MLS-9124/BNLA-601
		NCHB-9902 Bt2, NCHB-9903 Bt2, NCHB-9904 Bt2, NCHB-9905 Bt2, NSPL 252 BG II, NSPL 531 BGII, NSPL 2223BGII, NCHB-945 Bt, NSPL-333 BGII, NSPL-432 BGII, NSPL-666 BGII, NSPL-36, NSPL-405, NSPL-999, PCHB-9969 Bt2, PCH-9613 Bt2, PCH-9614 Bt2, PCH-9616 Bt2, PCH-9619 Bt2, PCH-9620 Bt2, Paras Lakshmi, PCH-115 Bt2, PCH-881 Bt2, PCH-882 Bt2, PCH-2171 Bt 2, PCH-205 Bt 2, PCH 105 BGII, PCH 404 BGII, PCH 360 BGII, PCH 789 BGII, PCH 884 BGII, PCH 885 BGII, PCH 887 BGII, PCH 888 BGII, PCH 9605 BGII, PCH 1411 BGII, PCH 2234 BG-II, PCH 4599 BG-II, PCH 549 BG-II, PRCH 731 BGII, PRCH 737 BGII, PRCH 739 Bt 2 BGII, PRCH 745 BGII, PRCH 746 BGII, PRCH 31 BGII, PRCH 733 BGII, PRCH 732 BGII, PRCH 710 BGII, PRCH-331 Bt II, PRCH-333 Bt II, PRCH-504, PRCH-505, PRCH-701Bt2, PRCH-703 Bt2, PRCH-704 Bt2, PRCH-709 Bt2, PRCHB-601Bt2, PRCHB-602 Bt2, PRCH 758 BG-II, PRCH 1166 BG-II, PRCH 135 BG-II, PRCH 757 BG-II, RACHH 011 BG-II, RACHH 353 BG-II, RCH 668 BGII, RCH386 BGII, RCH 656 BGII, RCH 659BGII, RCH-608 BGII, RCH-377 BGII, RCH-530 BG-II, RCH-2, RCH-515, RCH-578, RCH-584, RCH 779 BG-II, RCHB 625 BG-II, RCHB 20 BG-II, Sarju BG II, Senapati BGII, SO7H878 BGII , Solar 77 BGII, Solar 72 BGII, Solar 65 BGII, Solar 56 BGII, Solar 66 BGII, Solar 60 BG II, Solar 76 BGII, Solar 75 BGII, SP 499 BGII, SP 7149BGII, SP7147B2, SP7157B2,SP7196B2 BGII , SP1171B2, SP904 B2, SP1016 B2, SP1170 B2, SP504 B2, SP 911 B2 BG- II, SRCH 99 BGII, SRCH 55 BGII, SRCH 33 BGII, SSB 92 BG-II, SSCH 555BGII, SSCH 444 BGII, SSCH 333 BGII, SRCH-222 BG-II, SRCH-402 BG-II, 54 SS 33 BG-II, 60 SS 66 BG-II, 69 SS 66 BG-II, SS 333 BG-II, SS 405 BG-II, SS 455 BG-II, SS 7 BG-II, Super -721BGII, Super - 931BGII, Super -965BGII, Super - 971BGII , Super -511BGII, Super -544BGII , Super 5 BGII, SWCH-4823 BGII, SWCH-4746 BGII, SWCH-4753 BGII, SWCH- 4765 BGII, SWCH-4790 BGII, SWCH-4800 BGII, SWCH-4776 BGII, SWCH-4749 BGII, SWCH- 4731BGII, SWCH-4751 BGII, SWCH-4754 BGII, SWCH-4769 BGII, SWCH-2 BG-II, SWCH-4708 BG-II, SWCH-4715 BG-II, SWCH-1 BG-II, SWCH-5017, SWCH-5011, Sudarshan BG II, TULASI-252 BGII, TULASI 171 BGII, TULASI 45BGII, TULASI 333 BGII, Tulasi- 135 BG-II, Tulasi- 144 BG-II, Tulasi- 162 BG-II, Tulasi- 117 BG-II, Tulasi-4, Tulasi-9, Tulasi-118, VBCH-1533BGII, VBCH-1537BGII, VBCH-1539BGII, VBCH-1542BGII, VBCH-1543BGII,	

Table 1. Listing of events, Bt cotton variety and hybrids in India, 2012

Zone	BG-I Hybrids	BG-II Hybrids	GFM/Event-I/MLS-9124/BNLA-601
		VBCH-1544BGII, 841-2(BGII), VBCH- 1511, VBCH-1516, VBCH-1519, VBCH- 1520, VBCH- 1521, VBCHB-1525, VBCHB-1526, VICH-311 BG-II, VBCH-1501, VBCH-1503 , VBCH-1505, VICH-312 BG-II, VICH-313 BG-II, VICH-314 BG-II, VICH-5 Bt, VICH-15, VICH-303 BG-II, VICH-301 BG-II, VICH-314 BG-II , Western NIROGI-51 BG-II, Western NIROGI- 108 BG-II, ZCH 501 Dhruv Gold BGII, ZCH 502 Super King BGII, ZCH 503 President Gold BGII, ZCH 504 Champion BGII, ZCH 508 Polaris BGII, ZCH 511 BGII, ZCH 541 BGII, ZCH 545 BGII 846-2(BGII), ZCH-547 BG-II, ZCHB 550 BG-II, 844-2(BGII), 563-2 (BGII), 842-2 (BGII), 847-2 (BGII), 7213-2 (BGII), 7215-2 (BGII), 311-2, 557-2 , 110-2, 111-2, 195-2, 901-2 BG-II, 6188-2 BGII, 7211-2 BG-II	
South Zone (610 Hybrids 6 Events, 43 Companies)	ABCH 231 Bt, ABCH-172 Bt, ABCH-173 Bt, ABCH-174 Bt, ABCH-177 Bt, ABCH-178 Bt, ABCH-3083 Bt, ABCH-3483 Bt, ABCH-1165, ABCH-1220, ACHB-901-1 Bt, ACH-1 Bt, ACH 21-1, ACH 33-1, ACH 155-1, Akka, Ankur-238 Bt, Ankur-3082 Bt, Ankur HB 1024 Bt, Ankur-3042 Bt, Ankur HB-1902 Bt, Ankur HB-1976 Bt, Brahma, Dyna, GK-207, GK-209, Jai Bt, KCH-135, KCH-707, Mahasangram BG, KDCHH 553 BGI , KDCHH-507 BG-I, KDCHB-407, KDCHH-9632, KDCHH-9810, KSCH 201, KSCH 204, MECH-162*, MECH-184*, MRC-6322, MRC-6918, NCS-1911 Bt, NCS-1912 Bt, NCS-1913, NCS-1914 Bt, NCS-145 (Bunny), NCS-207 (Mallika), NCS-913, NCS-929, NCS-950, NCS-954, NCS-906 Bt, NCS-907 Bt, NCS-908 Bt, NCS-909 Bt, NCS-910 Bt, NCHB-940 Bt, NCHB-945 Bt, NCHB-990, NCHB-992, NPH-2171, NSPL-9, NSPL-36, NSPL-603, NSPL-666, NSPL-405, NSPL-999, Ole, PCH-1410 Bt, PCH 1411 Bt, PCH 1412 Bt, PCH-1413 Bt, PCH-115, PCH-207 (PCH 205), PCH-409 Bt, PCH-930, PCH-2270, PRCHB-405, PRCH-31 Bt, PRCH 724 Bt, PRCH 725 Bt, RCH-2, RCH-20, SP1136 BI (BGI), RCH-111, RCH-371, RCH-368, RCHB-708, Rudra, Sigma, SP 1170 B1, SP1016 B1,	ABCH 224 Bt, ABCH 225 Bt, ABCH 227 Bt, ABCH 229 Bt, ABCH 230 Bt, ABCH 240 Bt, ABCH 241 Bt, ABCH 243 Bt, ABCH 244 Bt, ABCH 245 Bt, ABCH 246 Bt, ABCH 247 Bt, ABCH 248 Bt, ABCH 252 Bt, ABCH 254 Bt, ABCH 256 Bt , ABCH-143 Bt BG-II, ABCH-146 Bt BG-II, ABCH-147 Bt BG-II, ABCH-148 Bt BG-II, ABCH-1299 Bt BG-II, ABCH-7399 Bt BG-II, ABCH-181 Bt BG-II, ABCH-182 Bt BG-II, ABCH-191 Bt BG-II, ABCH-192 Bt BG-II, ABCH-1065 Bt, ABCH-1020 Bt, ACH-5 (Ajeet 5) BGII, ACH-6 (Ajeet 6) BGII, Paramveer (ACH-12-2 BGII), ACH-33-2, ACH-177-2, ACH-155-2, ACH 133-2 (Ajeet133) BG-II, ACH 11-2 (Ajeet 11) BG-II, ACH 111-2 (Ajeet 111) BG-II, ACH 199-2 (Ajeet 199) BG-II, ACHH 2 BG-II, ACHH-3 BG-II, ACHB 901-2 (Ajeet 901) BG-II, Aditya 455 (SS 455) BG-II, ANKUR 3224 BGII, ANKUR 3244 BGII, ANKUR 3228 BGII, Akka, Ankur-3028 BG-II, Ankur-3034 BG-II, Ankur-257 BG-II, Ankur-356 BG-II, Ankur-3066 BG-II, Ankur HB 2110 BG-II, Ankur-5642, Ankur-10122, Atal BGII, BAT HH 210 BGII, BAT HH 218 BGII, Brahma, D-29 BG-II, DBH-2 BG-II, , DPC 7064 BGII, DPC 7065 BGII, DPC 9083 BG-II, DPC 9066 BG-II, DPC 9062 BG-II, EGCH 1513 BGII, Gautami (SS 11) BG-II, GBCH-85 BG-II (KUBER BG-II), GBCH-95 BG-II (VARDAN BGII), GBCH-8888 BG-II, GBCH-9999 BG-II, GK 220 BGII, GK 228 BGII, GK 238 BGII, GK 239 BGII, GK 241 BGII, GK-218 BGII, GK-221 BGII, GK-223 BGII, GK-224 BGII, GK-231 BGII, GK-235 BGII, GK-217, Jai BG-II, JKCH 99 DOUBLE Bt (JKCH 99 BG II), JKCH 2245 DOUBLE Bt (JKCH 2245 BG II), JK DURGA DOUBLE Bt (JK Durga BG II) , JKCH 8665 BG-II, JKCH 0034 BG-II, JKCH 8836 BG-II, NDRA VAJRA DOUBLE Bt (Indra Vajra BG II) ,	Dhruv Bt, GBCH-04Bt, GBCH-07 Bt, Kashinath, MH 5225 Bt, MH 5234 Bt, MH 5243 Bt, MH 5274 Bt, Monsoon Bt, NBC-3 Fusion-Bt, NCEH-2R, NCEH-3R, NCEH-13 Bt, NCEH-34 Bt, NCEH-14 Fusion-Bt, NCEH-21 Fusion-Bt, SSB-71Bt, SSB-72Bt, SBCH-311Bt, SBCH-310 Bt, SBCH-292 Bt, TPHCN07-015 Bt, TPHCN07-005 Bt, TPHCN07-009 Bt, UPLHH-189 Bt, UPLHH-7 Bt, UPLHH-295 Bt, UPLHH-355 Bt, UPLHH-358 Bt, UPLHH-360 Bt, UPLHH-347 Bt, UPLHH-265 Bt, UPLHH-271 Bt, UPLHH-10 Bt, YRCH-4 Bt, YRCH-9 Bt, YRCH- 13 Bt, YRCH-31 Bt, YRCH-45 Bt,YRCH- 54 Bt, YRCH 18 Bt, YRCH 22 Bt, YRCH 36 Bt,YRCH 40 Bt, UPLHH-12 Bt, UPLHH-5 Bt, ZCH-50072 Bt, ***JK COMMANDER Bt(JKCH-2253 Bt), JK KANAKADURGA Bt (JKCH-2004 Bt), JK SUPER STAR Bt (JKCH-2247 Bt), INDRA VAJRA ,JK SUPER VARUN Bt, JKCH-1305 Bt, JKCHB-229 Bt, JK-Durga, JKCH-99, JKCH-634 (JK-Iswar), JKCH-2245 Bt, JK Chamundi Bt, JK-Indra Bt, JK-Gowri Bt, JKCH 226 Bt, PCH-66Bt, PCH-55Bt, PCH-44Bt, PCH- 22Bt, PCH-99 Bt, PCH-77 Bt, PRCH-712 Bt, PRCH-713 Bt, PRCH-714 Bt, PRCH-715 Bt,***

Table 1. Listing of events, Bt cotton variety and hybrids in India, 2012

Zone	BG-I Hybrids	BG-II Hybrids	GFM/Event-I/MLS-9124/BNLA-601
	SP911B1, SP-503, SP-504 (Dhanno), SP-700, SWCH-4428 Bt, SWCH-4531 Bt, SWCH-4314 Bt, Tulasi-9 Bt, Tulasi-4, Tulasi-45 Bt,Tulasi-117, Tulasi-118 Bt, VBCHB-1010 BG, VBCH-1016 Bt,VBCH-1018 Bt, VBCHB-1203,VICH-5, VICH-9, VCH-111, 118 Bt, 340 Bt, 6188 Bt	I IAHH-2 BG-II, IAHH 178 BG- II, IAHB-78 BG-II, KCH-108 BGII, KCH-111 BGII, KCH-144 BGII, KCH-711 BGII , KCH- 100BGII, KCH-172BGII, KCH-189BGII, KCH-311BGII , KCH-707 BGII, KCH-14K59 BGII, KCH-15K39 BGII, KCH-36 BGII, KCH-999 BGII, KCH-135 Bt, KCHH-2505 BG-II, KCHH-8152 BG-II, KSCH-212 BG-II, KDCHH-541 BGII, KDCHB-407 BG-II, KDCHH-441, KDCHH-621, KDCHH-9632, KDCHH 641 BG II, KDCHH 9810 BG II, KDCHH 02 BGII, KDCHH 532 BGII, KDCHH 018 BGII, KDCHH 065 BGII, KDCHH 202 BGII, KDCHH 722 BGII, KDCHH 850 BGII, KSCH 207, Mahasangram BGII, MRC-7361 BGII,MRC-7375 BGII, MRC-7377 BGII, MRC-7385BGII, MRC-7387 BGII , MLBCH6 BGII, MLCH-318, MRC-7373 BGII, MRC-7383 BGII, MRC-7160, MRC-7918, MRC-7201, MRC-7347, MRC-7351, MRC-7929, MRC 7017 Plus BGII, MRC 7351 GOLD BG-II, MRC 6918 XXL BGII, MRC 7388 BG-II, MRC 7391 BG-II, MH 5343 BG-II, MH 5361 BG-II, MH 5362 BG-II, MH 5363 BG-II, NAMCOT 610 BGII, NAMCOT 622 BGII, NAMCOT 803 (HB) BG II , NAMCOT-612, NAMCOT-607, NAMCOT-604 BG-II, NAMCOT-605 BG-II, NAMCOT-614 BG-II, NAMCOT-615 BG-II, NCS 9014 Bt 2, NCS 9015 Bt 2, NCS 9025 Bt2, NCS 9028 Bt2, NCS 9030 Bt2, NCS 950 Bt2, NCS 954 Bt2, NCS 955 Bt2, NCS 929 Bt2, NCS 138 Bt2, NCS 856 Bt2, NCS 858 Bt2, NCS-854, NCS-207, NCS-145 (Bunny), NCS 567 BGII, NCS 9012 BGII, NCS 189 BGII, NCS 459 BG-II, NCS 456 BG-II, NCS 256 BG-II, NCS 245 BG-II, NCS 731 BG-II, NCS 909 BG-II, NCS 3112 BG-II, NCS 3114 BG-II, NCS 2123 BG-II, NCS 1024 BG-II, NCS 2340 BG-II, NCS 2434 BG-II, NCS 1134 BG-II, NCS 7788 BG-II, NCS 279 BG-II, NCS 1012 BG-II, NCS 589 BG-II, NCS 927 BG-II, NCS 1818 BG-II, NCS 1111 BG-II, NCS 1001 BG-II, NCS 1446 BG-II, NCS 9011 BG-II, NCS 1789 BG-II, NCS 6566 BG-II, NCS 1122 BG-II, NCS 2255 BG-II, NCS 3456 BG-II, NCHB 9901 Bt 2, NCHB 9902 Bt2, NCHB 9903 Bt2, NCHB 9904 Bt2, NCHB 9905 Bt 2, NCHB 990 Bt 2, NCHB 991 Bt 2, Neo 1631 BG-II, Neo 1651 BG-II, Neo 1601 BG-II, NSPL 252 BG II, NSPL 531 BG II, NSPL 2223BGII , NSPL-432 BGII, NSPL-333 BGII, NSPL-405, NSPL-999, Paras Laxmi BGII, PCH 9605 BGII, PCH 789 BGII, PCH 9613 Bt 2, PCH 9614 Bt 2, PCH 9616, PCH 9619 Bt 2, PCH 9620 Bt2, PCH-884 Bt2, PCH-887 Bt2, PCH-888 Bt2, PCH-115 Bt2, PCH-881 Bt2, PCH-882 Bt2, PCH-885 Bt2, PCH-886 Bt2, PCH-205 Bt2, PCH-2171 Bt2,	**MH-5125Bt, MH- 5174Bt, BN Bt (Variety)***

Table 1. Listing of events, Bt cotton variety and hybrids in India, 2012

Zone	BG-I Hybrids	BG-II Hybrids	GFM/Event-I/MLS-9124/BNLA-601
		PCH-2270, PCH-105, PCH 360 BGII, PCH 5678 BGII, PCH 2234 BG-II, PCH 108 BG-II, PCH 404 BG-II 15985, PCH 468 BG-II, PCH 556 BG-II, PCH 956 BG-II, PCH 1008 BG-II, PCH 1411 BG-II, PCH 4599 BG-II, PCH 549 BG-II, PCHB 9969 Bt2 , PCHH-4 BG-II, PCHH-6 BG-II, PRCH 731 BGII, PRCH 701 Bt2, PRCH 703 Bt2, PRCH 704 Bt2, PRCH 709 Bt2, PRCH 710 Bt2, PRCHB 601 Bt2, PRCHB 602 Bt2, PRCH-331 BG-II, PRCH-333 BG-II, PRCH-504, PRCH-505, PRCH 7776 BGII, PRCH 1166 BG-II, PRCH 135 BG-II, PRCH 737 BG-II, PRCH 733 BG-II, PRCH 2257 BG II, PRCH 732 BG-II, PRCH 7777 BG-II, PRCH 753 BG-II, PRCH 754 BG-II, PRCH 752 BG-II, PRCH 746 BG-II, PRCH 742 BG-II, PRCH 745 BG-II, RCH 665 BGII, RCH 668 BGII, RCH 578BGII, RCH-20 BG-II, RCH-656 BGII, RCH-659 BGII, RCHB- 625 BGII, RCHB 708 BG-II, RCH-111BGII, RCH-2, RCH-530, RCH-533, RCH-596, RACHH 011 BG-II, RACHH 353 BG-II, RACHH 533 BG-II, SARJU BG-II, SB-546 BG-II, SP 7149 BGII, SP-1171 B2, SP 504 B2 (Dhanno) BG II, SP911B2, SP904B2, SP-1037, SP1170 B2, SP7147 B2, SP7157 B2, SP7196 B2 (BGII), SP 7235 BG-II, SRCH 99 BGII, SRCH 55 BGII, SRCH 33 BGII, SRCH-222 BG-II, SRCH-402 BG-II, SSB-94 BG-II, SSB-95 BG-II, SSCH 333 BGII, SSCH 444 BGII, SSCH 555 BGII, SS 333 BG-II, SS 405 BG-II, SS 1119 BG-II, SWCH 4776 BGII, SWCH 4823 BGII, SWCH 4746 BGII, SWCH 4753 BG II, SWCH 4765 BG II, SWCH 4790 BGII, SWCH 4800 BGII, SWCH 4749 BG II, SWCH 4731 BGII, SWCH 4751 BGII, SWCH 4754 BG II, SWCH 4769 BG II , SWCH-2 BG-II, SWCH-4708 BG-II, SWCH-4703 BG-II, SWCH-4715 BG-II, SWCH-4720 BG-II, SWCH-5017 BG-II, SWCH-5011 BG-II, Senapati BGII, Solar 76 BGII, Solar 75 BGII, SOLAR-66 BG-II, SOLAR 72 BGII, SOLAR-60 BG-II, Sudarshan BGII, Super -721BGII, Super -931BGII, Super -965BGII,Super -971BGII, Super-511BGII, Super -544BGII, Super-5 BG-II, TULASI-162 BGII, TULASI 171 BGII, TULASI 216 BGII, TULASI 234 BGII, TULASI 243 BGII, Tulasi-135 BG-II, Tulasi-144 BG-II, Tulasi-252 BG-II, Tulasi-4 BG-II, Tulasi-45 BG-II, Tulasi-117 BG-II, Tulasi-333 BG-II, Tulasi-7, Tulasi-9, Tulasi-118, VBCH 1533 BGII, VBCH 1537 BGII, VBCH 1539 BGII, VBCH 1542 BG II, VBCH 1543 BG II, VBCH 1544 BGII, VBCHB-1525 BG-II, VBCHB-1526 BG-II, VBCH-1511 BG-II, VBCH-1516 BG-II, VBCH-1519 BG-II, VBCH-1520 BG-II, VBCH-1521 BG-II, VBCH-1501, VBCH-1505, VBCH-1506, VICH-301 BG-II, VICH-303 BG-II, VICH-304 BG-II, VICH-311 BG-II,	

Table 1. Listing of events, Bt cotton variety and hybrids in India, 2012

Zone	BG-I Hybrids	BG-II Hybrids	GFM/Event-I/MLS-9124/BNLA-601
		VICH-312 BG-II, VICH-313 BG-II, VICH-314 BG-II, VICH-5 Bt,VICH-15 Bt, Western NIROGI-51 BG-II, Western NIROGI- 108 BG-II, Western Nirogi 555 BG-II, ZCH 501 Dhruv Gold BGII, ZCH 502 Super King BGII, ZCH 503 President Gold BGII, ZCH 504 Champion BGII, ZCH 508 Polaris BGII, ZCH 541 Robo BGII, ZCH-545 BG-II, ZCH-547 BG-II, 563-2, 7211-2, 7213-2, 7215-2 BG II, 110-2, 118-2, 61888-2, 322-2, 113-2, 340-2, 54 SS 33 BG-II, 60 SS 66 BG-II, 69 SS 66 BG-II, 45 SS 33 BG-II	

* A hybrid and a variety of Event BNLA-601 discontinued since 2010.
Source: Compiled by ISAAA, 2012

978-1-892456-53-2

978-1-892456-53-2