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BRIEF 49

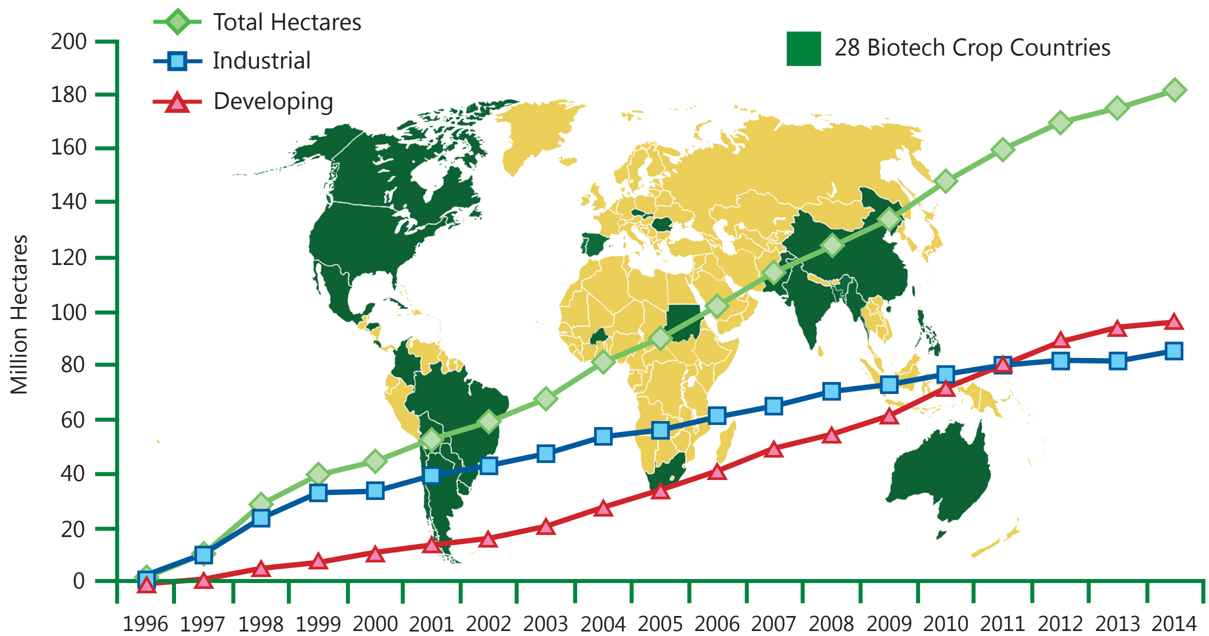
Global Status of Commercialized Biotech/GM Crops: 2014

By

Clive James
Founder and Emeritus Chair of ISAAA

Dedicated to the late Nobel Peace Laureate, Norman Borlaug, founding patron of ISAAA, on the centenary of his birth, 25 March 2014

GLOBAL AREA OF BIOTECH CROPS
Million Hectares (1996-2014)



A record 18 million farmers, in 28 countries, planted 181.5 million hectares (448 million acres) in 2014, a sustained increase of 3 to 4% or 6.3 million hectares (~16 million acres) over 2013.

Source: Clive James, 2014.

No. 49 - 2014

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 2014 information for Argentina, Brazil, Australia, South Africa, and Uruguay is hectares usually planted in the last quarter of 2014 and harvested in the first quarter of 2015 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 2014 and more intensively through January and February 2015 is classified as a 2014 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. Importantly, all reported biotech crop hectares are for officially approved and planted products, and do not include unofficial plantings of any biotech crops. At the time when this Brief went to press, estimates of economic benefits, productivity, landsaving, and carbon data were provisional for the period 1996-2013 (Brookes and Barfoot, 2015, Forthcoming); and pesticide data is for 1996-2012 (Brookes and Barfoot, 2014). Details of the references listed in the Executive Summary are found in the full Brief 49.

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ISAAA prepares this Brief and supports its free distribution to developing countries. The objective is to provide information and knowledge to the scientific community and society on biotech/GM crops to facilitate a more informed and transparent discussion regarding their potential role in contributing to global food, feed, fiber and fuel security, and a more sustainable agriculture. The author takes full responsibility for the views expressed in this publication and for any errors of omission or misinterpretation.

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Tables

<u>Figures</u>

Global Status of Commercialized Biotech/GM Crops: 2014

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TOP TEN FACTS about Biotech/GM Crops in 2014

FACT # 1. 2014 was the 19th year of successful commercialization of biotech crops. Since the first plantings in 1996, an unprecedented cumulative hectarage of more than 1.8 billion hectares (more than 4 billion acres for the first time) have been successfully cultivated, equivalent to ~80% more than the total land mass of China or the United States. Biotech crop hectares were planted in 28 countries in 2014 and hectarage has increased more than 100-fold from 1.7 million hectares in 1996 to 181.5 million hectares in 2014 – a 6.3 million hectare increase compared to 5.0 million hectares in 2013 at an annual growth rate of between 3 to 4%. A 100-fold increase makes biotech crops the fastest adopted crop technology in recent times – the reason – they deliver benefits. Number of biotech countries has more than quadrupled from 6 in 1996 to 28 in 2014, up one from 2013.

FACT # 2. Number of farmers planting biotech crops. In 2014, 18 million farmers, of which 90% were small and poor, planted a record 181 million hectares of biotech crops in 28 countries. Farmers are the masters of risk-aversion and improve productivity through **sustainable intensification** (confining cultivation to the 1.5 billion hectares of cropland, thereby saving the forests and biodiversity). Thus, 7.1 million small farmers in China and 7.7 million in India elected to plant over 15 million hectares of Bt cotton in 2014 because of the significant benefits it offers. Similarly in 2014, 415,000 small farmers in the Philippines benefited from biotech maize.

FACT # 3. Strong political will allowed Bangladesh to commercialize Bt brinjal (eggplant) for the first time. Notably, Bangladesh, a small poor country with 150 million people, approved the prized vegetable Bt brinjal/eggplant on 30 October 2013, and in record time – less than 100 days after approval – small farmers planted Bt brinjal on 22 January 2014. This feat could not have been achieved without strong Government support and political will, particularly from the Minister of Agriculture Matia Chowdhury – the experience is exemplary for small poor countries. Bangladesh is already field testing biotech potatoes and exploring biotech cotton and rice.

FACT # 4. Some of the "new" biotech crops, recently approved for planting, include food staples – potato in the US and the vegetable brinjal (eggplant) in Bangladesh. In 2014, the US approved two "new" biotech crops for cultivation: Innate™ potato, a food staple with lower levels of acrylamide, a potential carcinogen, and less wastage due to bruising; and a reduced lignin alfalfa event KK179 (HarvXtra™) with higher digestibility and yield (alfalfa is #1 forage crop in the world). Indonesia approved a drought tolerant sugarcane. Brazil approved Cultivance™, a HT soybean, and a home-grown virus resistant bean, ready for planting in 2016. Vietnam approved biotech maize (HT and IR) for the first time in 2014. In addition to the current biotech food crops which directly benefit consumers (white maize in South Africa, sugar beet and sweet corn in the US and Canada, and papaya and squash in the US) new biotech food crops include the queen of the vegetables (brinjal) in Bangladesh and potato in the US – potato is the fourth most important food staple globally and can contribute to food security in countries like China (6 million hectares of potato), India (2 million) and the EU (~2 million).

FACT # 5. The top 5 countries planting biotech crops. The US continued to be the lead country with 73.1 million hectares (40% of global) with over 90% adoption for the principal crops of maize (93% adoption) soybean (94%) and cotton (96%). Whereas Brazil has been #1 in year-to-year hectare growth for the last five years, the US ranked #1 in 2014, with 3 million hectares, compared to 1.9 million hectares for Brazil. Notably, Brazil planted the stacked HT/IR soybean on a record 5.2 million hectares in its second year after the launch. Argentina retained third place, down marginally with 24.3 million hectares, from 24.4 million in 2013. India ranked fourth, had a record 11.6 million hectares of Bt cotton (11.0 in 2013), and 95% adoption. Canada was fifth at 11.6 million hectares also, with more canola and a high 95% adoption. In 2014, each of the top 5 countries planted more than 10 million hectares providing a broad, solid foundation for future sustained growth.

FACT # 6. The first biotech drought tolerant maize planted in the US in 2013 increased more than 5-fold in 2014. Biotech DroughtGard™ tolerant maize, first planted in the US in 2013, increased 5.5-fold from 50,000 hectares in 2013 to 275,000 hectares in 2014 reflecting farmer acceptance – the same event was donated to the public-private partnership, Water Efficient Maize for Africa (WEMA) aimed at delivering biotech drought tolerant maize to selected countries in Africa by 2017.

FACT # 7. Status of biotech crops in Africa. The continent continued to make progress with South Africa, marginally lower at 2.7 million hectares mainly due to drought. Sudan increased Bt cotton hectarage by almost 50%, whilst drought precluded a potentially higher hectarage than 0.5 million hectares in Burkina Faso. An additional seven countries (Cameroon, Egypt, Ghana, Kenya, Malawi, Nigeria and Uganda) conducted field trials on pro-poor crops, the penultimate step prior to approval. Importantly, the WEMA project is scheduled to deliver the first stacked biotech drought tolerant (DT) maize with insect control (Bt) in South Africa in 2017. Lack of science-based and cost/time-effective regulatory systems is the major constraint to adoption. Responsible, rigorous but not onerous, regulation is urgently needed to suit the needs of small famers and poor developing countries.

FACT # 8. Status of biotech crops in the EU. Five EU countries continued to plant 143,016 hectares down marginally by 3% from 2013. Spain led with 131,538 hectares of Bt maize, down 3% from 2013, but with a record 31.6% adoption. In summary, there were modest increases in three EU countries and slight decreases in two countries, due mainly to less planting of maize and bureaucracy.

FACT # 9. Benefits offered by biotech crops. A new 2014 global meta-analysis confirmed significant multiple benefits, during the last 20 years. A global meta-analysis of 147 studies in the last 20 years, confirmed that "on average GM technology adoption has reduced chemical pesticide use by 37%, increased crop yields by 22%, and increased farmer profits by 68%." These findings corroborate earlier and consistent results from other annual global studies. The latest provisional data for 1996 to 2013, showed that biotech crops contributed to Food Security, Sustainability and Environment/Climate Change by: increasing crop production valued at US$133 billion; providing a better environment, by saving ~500 million kg a.i. of pesticides from 1996 to 2012; in 2013 alone reducing CO_2 emissions by 28 billion kg, equivalent to taking 12.4 million cars off the road for one year; conserving biodiversity by saving 132 million hectares of land from 1996-2013; and helped alleviate poverty for >16.5 million small farmers and their families totaling >65 million people, who are some of the poorest people in the world. Biotech crops are essential but are not a panacea – adherence to good farming practices such as rotations and resistance management, are a must for biotech crops as they are for conventional crops.

FACT # 10. Future Prospects. Cautiously optimistic with modest annual gains expected due to the already high rates of adoption (90% to 100%) in the current principal biotech crops, leaving little room for expansion in mature markets in both developing and industrial countries. The pipeline is full of new biotech crop products which could (subject to regulatory approval for planting and import) be available during the next 5 years or so – a list of over 70 potential products are listed in the full Brief. They include, a broad range of new crops and traits as well as products with multiple modes of resistance to pests/diseases and tolerance to herbicides; Golden Rice is progressing with field testing and late-blight resistant potatoes are being field tested in Bangladesh, Indonesia, and India. In the US, Simplot has already requested approval for an enhanced Innate™ potato with late-blight resistance and lowered reducing sugars; pro-poor crops, particularly in Africa, such as fortified bananas and pest resistant cowpea, look promising; public-private partnerships (PPP) have been relatively successful in developing and delivering approved products – four PPP case studies, featuring a broad range of different crops and traits in all three continents of the South, are reviewed in the full Brief.

Global Status of Commercialized Biotech/GM Crops: 2014

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Founder and Emeritus Chair, ISAAA

Introduction

This Brief focuses on the global biotech crop highlights in 2014. It is dedicated to the late Nobel Peace Laureate, Norman Borlaug (founding patron of ISAAA) on the centenary of his birth, 25 March 2014. Borlaug is credited with saving 1 billion poor from hunger.

2014 marks the 19th anniversary (1996-2014) of the commercialization 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 18 years of commercialization, 1996 to 2013, 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 18 years of commercialization, 1996 to 2013, 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 2013, developing and industrial countries contributed more than 100-fold increase in the global area of biotech crops from 1.7 million hectares in 1996 to 175 million hectares in 2013. Adoption rates for biotech crops during the period 1996 to 2013 were unprecedented and, by recent agricultural industry standards, they represent the highest adoption rates for improved crops, for example, as high, or 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 and conveniences 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 in 12 years since 1996, because of the significant multiple benefits and advantages 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. There were 18 million farmers in 27 countries that grew biotech crops in 2013 and derived multiple benefits that included significant agronomic, environmental, health, social and economic advantages. ISAAA's 2013 Global Review (James, 2013) predicted that the global area of biotech crops, would increase in 2014 but probably grow more modestly. Global population was approximately 7.2 billion in 2013 and is expected to reach approximately up to 9.6 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, 2012 World Population Prospects: The 2012 Revision) is that the population will continue to increase until the end of this century when it will plateau at 10.8 billion, or more. In 2012-2014, close to 1 billion (805 million) people in the developing countries suffered from hunger, malnutrition and poverty (FAO, 2014). 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 comprehensive study in 2011 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, 2013; James, 2012; James 2011; James, 2010a; 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 2014 and the changes that have occurred between 2013 and 2014 are highlighted. The global adoption trends during the last 19 years from 1996 to 2014 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 49 for 2014, is the nineteenth in an annual series. It documents the global database on the adoption and distribution of biotech crops in 2014, and supported by five sections in the Appendix: 1) a table with global status of crop protection in 2014, courtesy of Cropnosis; 2) useful tables and charts on the international seed trade – these have been reproduced with the permission of the International Seed Federation (ISF); 3) estimated value of the domestic seed market in selected countries for 2012; 4) arable land per capita in selected developing countries; 5) and population of 28 planting countries in 2100; 6) commercial release of different Bt cotton varieties and hybrids in Pakistan between 2010 and 2014; 7) list of selected biotech crops at various stages of field testing in different countries; and 8) miscellaneous data and conversions.

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 2014 information for Argentina, Brazil, Australia, South Africa, and Uruguay is hectares usually planted in the last quarter of 2014 and harvested in the first quarter of 2015, 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 2014 and more intensively through January and February 2015, is classified as a 2014 crop in this Brief, consistent with a policy which uses the first date of planting to determine the crop year. All biotech crop hectare estimates in this Brief, and all ISAAA publications, are only counted once, irrespective of how many traits are incorporated in the crops. Country figures were sourced from The Economist, supplemented by data from World Bank, FAO and UNCTAD, when necessary.

Over the last 19 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 are those defined as food, feed and fiber crops in the FAO database, which totaled ~10 billion metric tons of production in 2010 (http://www.geohive.com. Charts/ag_crops.aspx). 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 19 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. Whereas individual data points make-up the data base, the most valuable information is the trends of adoption over time, for example the increasing dominance of developing countries which is clearly evident.

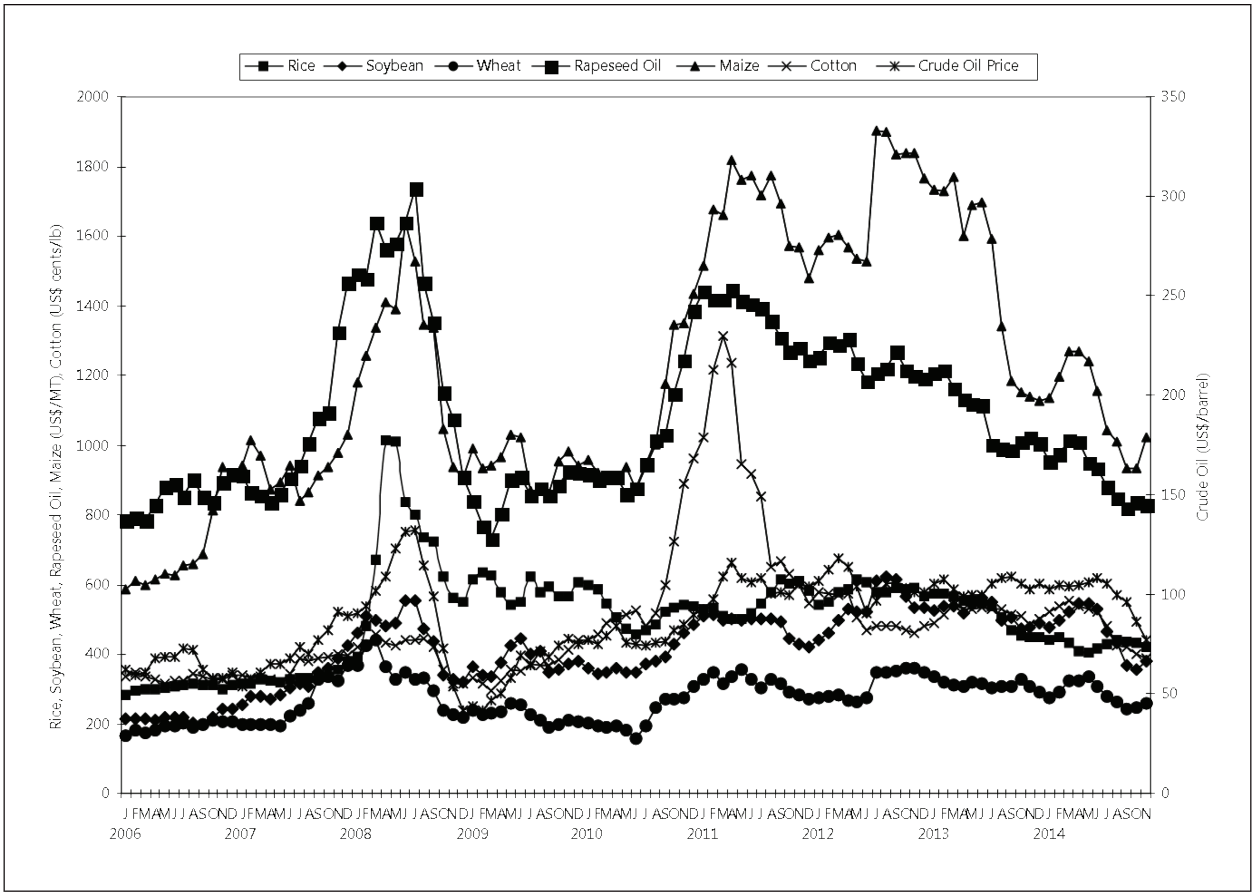
Global Area of Biotech Crops in 2014

International prices of maize soybean and canola (IMF data in Figure 1) have not retraced the high prices of 2008 and 2011/12. The prices of all four biotech crops have been low and this has created uncertainty for farmers. Given this situation, farmers in several countries have favored soybean over maize because soybean has lower production costs and is an easier crop to grow. Generally speaking, the prices of all four commodities have been low in 2014 with the US projecting a record harvest particularly, soybean. However many years of past positive experience with biotech crops have continued to provide incentives for farmers worldwide, resulting in increased hectarages of the principal crops (except maize) and making more investments in improved technologies, including biotech crops.

Thus, in 2014, a record 181.5 million hectares of biotech crops were planted by 18 million farmers (similar to 2013) in 28 countries, compared with 175.2 million hectares grown in 27 countries in 2013 (Table 1). Of the total number of 28 countries planting biotech crops in 2014, 20 were developing countries and 8 industrial countries (Figure 4). Importantly, Bangladesh planted its first biotech crop, Bt brinjal (eggplant). It is notable that a record 6.3 million hectares more were planted in 2014 by 18 million farmers in the 19th year of commercialization at a growth rate of between 3 to 4%. The highest increase in any country, in absolute hectarage growth, was the USA with 3 million hectares followed by Brazil at 1.9 million, and Canada at 0.8 million hectares; significant percentage increases were reported for India, Paraguay and Uruguay with Bt cotton, soybean, and maize (Table 3), all delivering significant benefits at the farm level. Some decreases in biotech crops were recorded in Australia because of extreme drought; and in Argentina, maize farmers prefer planting the more easily managed soybean instead of maize. Herbicide tolerant canola in Canada was up significantly with the same adoption rate of 95%, the same as 2013. India continued to retain fourth place in 2014, having displaced Canada in 2010. Australia biotech hectarage decreased because cotton plantings were down due to severe drought but adoption and commitment to biotech cotton was still very high at a 99% adoption. China had decreased Bt cotton due to lower total plantings and the same applies to South Africa with less maize and Burkina Faso with less Bt cotton – however in all these three countries adoption percentage remained high or higher compared with 2013.

From some points of view the biotech crop highlight of 2014 was Bangladesh, one of the poorest countries in the world, planting its first biotech crop Bt brinjal (eggplant). Eggplant is a very important food/vegetable crop in Bangladesh and is known as the "queen of the vegetables". This is clear evidence that through innovative philanthropic public-private partnerships (PPP), very small poor countries like Bangladesh, can access biotech crops provided there is the **political will** from

Figure 1. International Prices of Crop Commodities and a Barrel of Crude Oil, 2006 to November 2014



Source: International Monetary Fund, 2014.

government to support scientific innovation using science-based methodology. The government of Bangladesh provided exemplary support for the approval of Bt brinjal, in particular the Minister of Agriculture, Matia Chowdhury because without whose support the project would not have succeeded. The Bangladesh experience can serve as a very important model for other small and poor countries in all three continents of the South.

Another very important and growing feature witnessed in 2014 is the progress in the development and approval of home-grown biotech products by developing countries such as Brazil, Bangladesh and Indonesia through innovative PPP. Brazil has developed a home grown biotech virus resistant bean which was approved for commercialization in 2014 which will be planted in 2016. Bangladesh is benefiting from a home-grown biotech Bt brinjal developed through a PPP. Indonesia has also developed a home-grown biotech sugarcane that has already been recommended for commercialization approval for food by the regulation agencies in the country. Several countries in Africa stand to benefit from a drought-tolerant maize developed through a PPP and will feature a stacked DR/Bt product as early as 2017 in South Africa.

Table 1. Global Area of Biotech Crops, the First 19 Years, 1996 to 2014

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
2013	175.2	433.0
2014	181.5	448.5
Total	**1,784.9**	**4,413.5**

Increase of 3-4%, 6.3 million hectares (15.6 million acres) between 2013 and 2014.
Source: Clive James, 2014.

There is a continuing progress in 2014 in the development of Golden Rice which contains high beta carotene and is at the same time, high yielding. Other GR2 events such as event E have been tapped as sources of beta carotene genes in the introgression breeding strategy with popular mega varieties. This is a very important development and hopefully the progress in 2014 will provide a foundation for an early as possible approval to benefit the millions of malnourished children facing a life threatening future – for more details see the section on Golden Rice in this Brief.

It is noteworthy that due to the leadership of Spain, hectarage of Bt maize in the EU in 2014 at 143,474 hectares (compared with 148,013 in 2013, a 3% decrease) continues to be sustained at between 140,000 and 150,000 hectares, despite all the obstructions placed by the EU to approval and adoption of biotech crops. The decrease is mainly attributed to a 6% decrease in total maize planted by Spain in 2014. The five countries which planted Bt maize in 2014 were, in descending order of hectares, Spain, Portugal, Czech Republic, Romania and Slovakia. Spain plants over 92% of the EU hectarage of Bt maize, whilst there is a significant disincentive in other countries where onerous systems of reporting are a burden for farmers and for developers of biotech crops; several companies have chosen to exit the EU market because of the hostile environment for biotech crops in the EU and a lack of political will and support for the technology.

To put the 2014 global area of biotech crops into context, 181.5 million hectares of biotech crops is equivalent to almost 20% 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 2013 and 2014, of 3 to 4%, is equivalent to 6.3 million hectares or 15.6 million acres (Table 1).

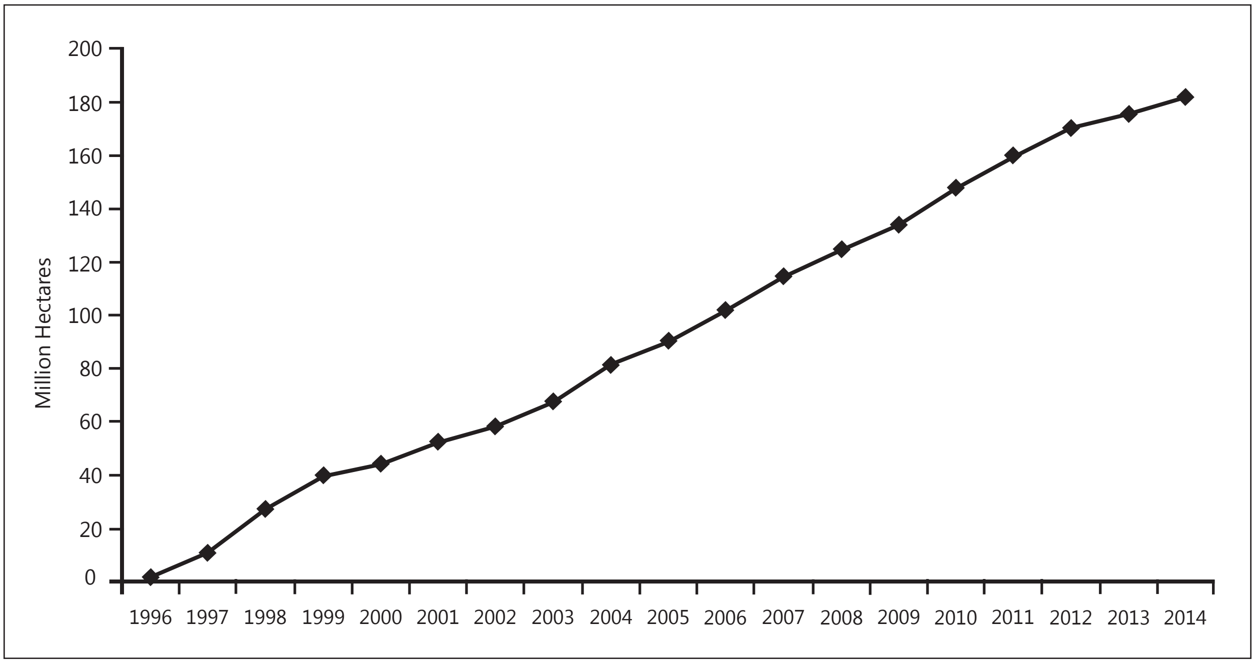
During the nineteen years of commercialization 1996 to 2014, the global area of biotech crops increased more than 100-fold, from 1.7 million hectares in 1996 to 181.5 million hectares in 2014 (Figure 2). This rate of adoption is the highest rate of crop technology adoption for any crop technology in recent times, and reflects the continuing and growing acceptance of biotech crops by farmers, by both large and small, resource-poor farmers in both 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, 28 in 2012, 27 in 2013 and 28 in 2014.

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 2014, with a strong indication that several new countries will join in the near term including Vietnam and Indonesia in 2015; notable and significant continuing progress in Africa with three countries (South Africa, Burkina Faso, and Sudan), collectively planting over 3.2 million hectares in 2014, and an additional seven countries conducting field trials with biotech crops. Africa is the continent with the greatest challenge as there are significant increases in field trials with "new" biotech pro-poor crops such as cassava. Brazil opens up significant additional potential hectarage for new biotech crops such as the IR/HT soybean launched in 2013 and which quickly occupied 5.8 million hectares in 2014 in four countries in Latin America led by Brazil.

A landmark development was the planting of the first biotech drought tolerant maize in the US in 2013 – notably the same drought technology that has been donated to five countries in Africa, through a public-private partnership (PPP) project named "Water Efficient Maize for Africa" (WEMA). The estimated hectares of DroughtGard™ maize with event MON 87460, planted in the US in 2013 was 50,000 hectares, and in 2014 was of the order of 275,000 hectares. This is equivalent to a large 5.5-fold year-to-year increase in planted hectares between 2013 and 2014 and reflects strong US farmer acceptance of the first biotech derived drought-tolerant maize technology to be deployed globally. It is noteworthy that Event MON 87460 was donated by Monsanto to the Water Efficient Maize for Africa (WEMA) a public-private partnership (PPP) designed to deliver the first biotech drought tolerant maize to selected African countries starting 2017.

Other milestones include the high demand for RR®alfalfa for seeding and the recent approval by the USDA APHIS of reduced lignin alfalfa event KK179 with higher digestibility and yield – alfalfa is the fourth largest crop in the US (8 million hectares) after maize, soybean and wheat; approval of the home-grown virus resistant bean in Brazil; continuing growth in stacked traits in cotton and maize, increasingly deployed by 13 countries worldwide, ten of which are developing countries and a new

Figure 2. Global Area of Biotech Crops, 1996 to 2014 (Million Hectares)



Source: Compiled by Clive James, 2014.

second generation of events with dual and triple mechanisms for pest resistance; progress with quality traits such as Golden Rice enriched with vitamin A, and soybean with healthier omega-3 oil; and late blight potato which is in field trials in Bangladesh, India, and Indonesia. Importantly, Innate™ potato with lower levels of acrylamide, a potential carcinogen and less wastage due to bruising has been given approval for commercialization in the US with commercial planting in 2015. In a pioneering strategy, Simplot has licensed biotech late blight resistant potato from the John Innes Institute in the UK, and has submitted to APHIS an application for non regulated status the Innate™ potato enhanced with late blight resistance and lowered reducing sugars. The application is already up for public comment.

A 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 2014, the accumulated hectarage (planted since 1996) surged to 1.8 billion hectares or 4.4 billion acres (Table 1). Developing countries continued to out-perform industrial countries by 10.9 million hectares and in 2014, for the second consecutive year, developing countries grew more than half (53%) of the global biotech crop hectarage of over 181.5 million hectares (Table 2). This trend of higher adoption by developing countries is expected to continue through 2015, the end of the second decade of commercialization, and beyond. By coincidence, 2015 also happens to be the Millennium Development Goal (MDG) 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% in 2015, to which biotech crops can make a significant contribution.

In summary, during the first nineteen years of commercialization 1996 to 2014, an accumulated total of ~1.8 billion hectares, equivalent to 4.4 billion acres of biotech crops, have been successfully grown (Table 1) as a result of ~100 million independent decisions by farmers to plant biotech crops. Farmers have signaled their strong vote of confidence in crop biotechnology by consistently sustaining and increasing their plantings of biotech crops 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 19-year period.

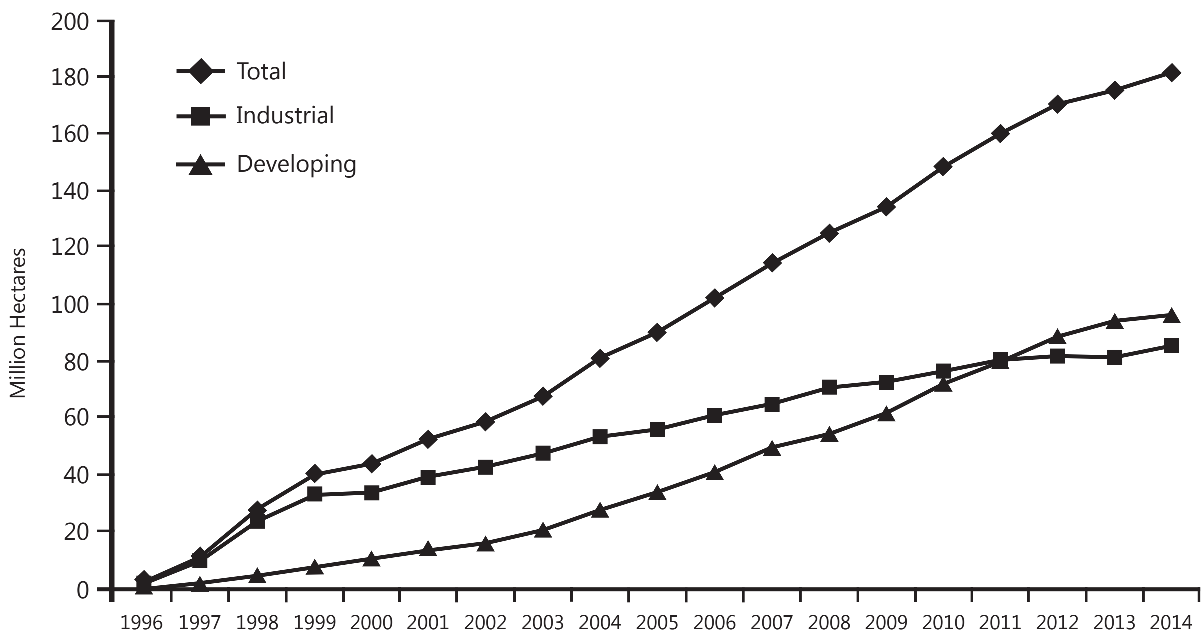
Distribution of Biotech Crops in Industrial and Developing Countries

Figure 3 shows the relative hectarage of biotech crops in industrial and developing countries during the period 1996 to 2014. It illustrates that in 2014 for the third time, developing countries planted more than half of the global biotech crops estimated at 181.5 million hectares in 2014. In 2014, developing countries, planted 53% (compared with 54% in 2013) equivalent to 96.2 million hectares. Industrial countries planted only 47% (compared with 46% in 2013 and equivalent to 81.1 million hectares (Table 2). Figure 3 illustrates that prior to 2014, 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, 52% in 2012 and 54% in 2013. Thus, in 2014, more than half (53%) of the global biotech crop area of 181.5 million hectares, equivalent to 96.2 million hectares, was grown in 20 developing countries; this compares with only 47% of the global areas grown in industrial countries equivalent to 85.3 million hectares. Unlike 2013, year-to-year growth was higher in the industrial countries at 4.2 million hectares (5%) than in developing countries at 2.1 million hectares equivalent to a 2% growth; this was principally due to higher growth in the US (soybean) and Canada (canola) in 2014. Thus, whereas year- to-year growth was significantly faster in industrial countries in 2014, developing countries maintained a larger share of global biotech crops at 53% compared with only 47% for industrial countries. The trend for a higher share of global biotech crops in developing countries is likely to continue in the near, mid and long-term, firstly, due to more countries from the South adopting biotech crops and secondly, adoption of crops like rice, 90% of which is grown in developing countries, are deployed as “new” biotech crops.

Distribution of Biotech Crops, by Country

A total of 28 countries, 20 developing and 8 industrial countries, planted biotech crops in 2014. The top ten countries, each of which grew over 1 million hectares in 2014, are listed by hectarage in Table 3 and Figure 4, led by the USA which grew 73.1 million hectares (40% of global total), Brazil with 42.2 million hectares (23%), Argentina with 24.3 million hectares (13%), India with 11.6 million hectares (6%), Canada with 11.6 million hectares (6%), China with 3.9 million hectares (2%), Paraguay with 3.9 million hectares (2%), Pakistan 2.9 million hectares (2%), South Africa 2.7 million hectares (2%), and Uruguay with 1.6 million hectares. An additional 18 countries grew a total of approximately 3.6 million hectares in 2014 (Table 3 and Figure 4). It should be noted that of the top ten countries, each growing

Figure 3. Global Area of Biotech Crops, 1996 to 2014: Industrial and Developing Countries (Million Hectares)



Source: Clive James, 2014.

Table 2. Global Area of Biotech Crops, 2013 and 2014: Industrial and Developing Countries (Million Hectares)

	2013	%	2014	%	+/-	%
Industrial countries	81.1	46	85.3	47	+4.2	+5
Developing countries	94.1	54	96.2	53	+2.1	+2
Total	**175.2**	**100**	**181.5**	**100**	**6.3**	**+3 to 4**

Source: Clive James, 2014.

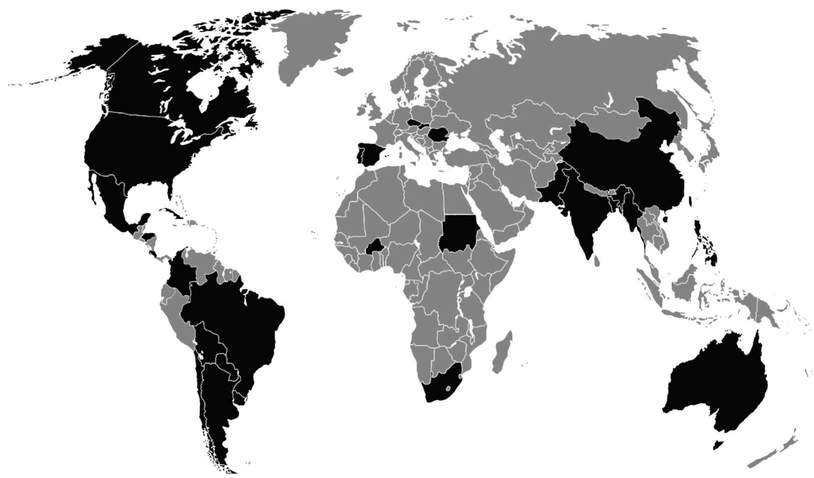
Table 3. Global Area of Biotech Crops in 2013 and 2014: by Country (Million Hectares)**

	Country	2013	%	2014	%	%+/-	%
1	USA*	70.1	40	73.1	40	3.0	+4
2	Brazil*	40.3	23	42.2	23	1.9	+5
3	Argentina*	24.4	14	24.3	13	-0 .1	- 0.4
4	India*	11.0	6	11.6	6	0.6	+5
5	Canada*	10.8	6	11.6	6	0.8	+7
6	China*	4.2	2	3.9	2	-0.3	-7
7	Paraguay*	3.6	2	3.9	2	0.3	+8
8	Pakistan*	2.8	2	2.9	2	0.1	+4
9	South Africa*	2.9	2	2.7	2	-0.2	-7
10	Uruguay*	1.5	1	1.6	1	0.1	+7
11	Bolivia*	1.0	1	1.0	1	0	0
12	Philippines*	0.8	<1	0.8	<1	0	0
13	Australia*	0.6	<1	0.5	<1	-0.1	-20
14	Burkina Faso*	0.5	<1	0.5	<1	0	0
15	Myanmar*	0.3	<1	0.3	<1	0	0
16	Mexico*	0.1	<1	0.2	0.1	0.1	+100
17	Spain*	0.1	<1	0.1	<1	0	0
18	Colombia*	0.1	<1	0.1	<1	0	0
19	Sudan*	0.1	<1	0.1	<1	<1	<1
20	Honduras	<0.1	<1	<0.1	<1	<1	<1
21	Chile	<0.1	<1	<0.1	<1	<1	<1
22	Portugal	<0.1	<1	<0.1	<1	<1	<1
23	Cuba	<0.1	<1	<0.1	<1	<1	<1
24	Czech Republic	<0.1	<1	<0.1	<1	<1	<1
25	Romania	<0.1	<1	<0.1	<1	<1	<1
26	Slovakia	<0.1	<1	<0.1	<1	<1	<1
27	Costa Rica	<0.1	<1	<0.1	<1	<1	<1
28	Bangladesh	--	--	<0.1	<1	<1	<1
	Total	**175.2**	**100**	**181.5**	**100**	**6.3**	**3 to 4%**

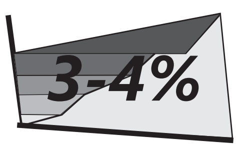
* Biotech mega-countries growing 50,000 hectares, or more.
** Rounded-off to the nearest hundred thousand.

Source: Clive James, 2014.

Figure 4. Global Area (Million Hectares) of Biotech Crops, 1996 to 2014, by Country, Mega-Countries, and for the Top Ten Countries



Increase over 2013



■ 28 countries which have adopted biotech crops

In 2014, global area of biotech crops was 181.5 million hectares, representing an increase of 3-4% over 2013, equivalent to 6.3 million hectares.

Source: Clive James, 2014.

Biotech Mega-Countries

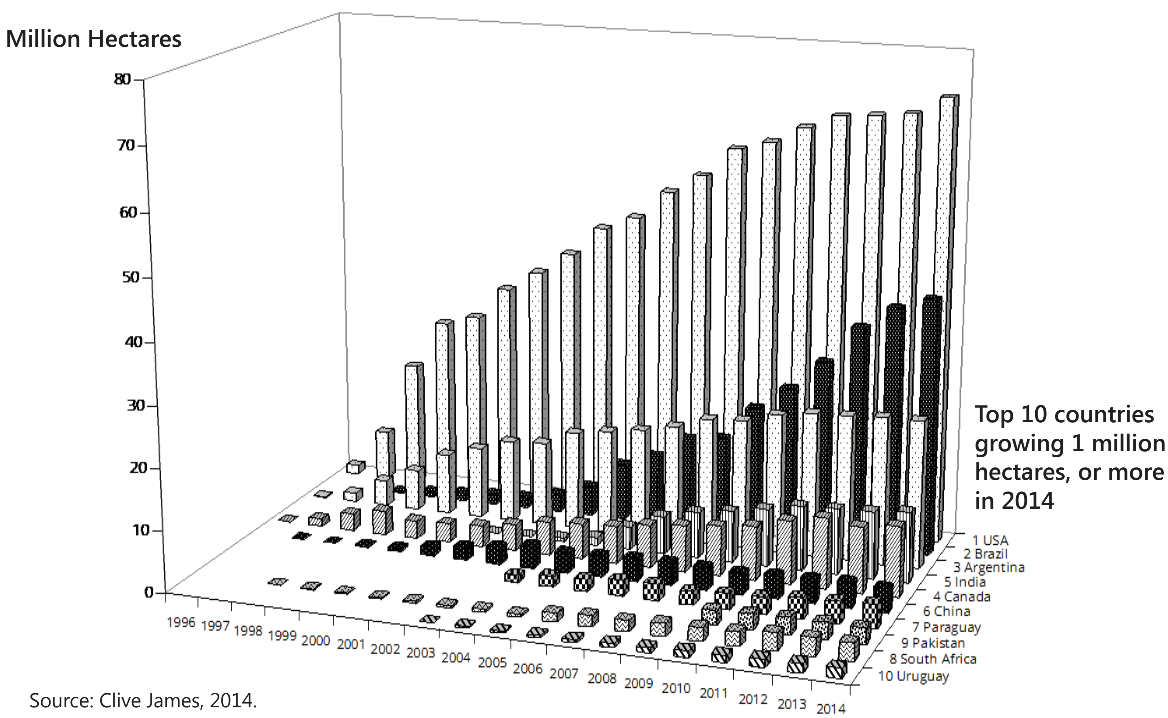
50,000 hectares, or more

1.	USA	73.1 million
2.	*Brazil**	42.2 million
3.	*Argentina**	24.3 million
4.	*India**	11.6 million
5.	Canada	11.6 million
6.	*China**	3.9 million
7.	*Paraguay**	3.9 million
8.	*Pakistan**	2.9 million
9.	*South Africa**	2.7 million
10.	*Uruguay**	1.6 million
11.	*Bolivia**	1.0 million
12.	*Philippines**	0.8 million
13.	Australia	0.5 million
14.	*Burkina Faso**	0.5 million
15.	*Myanmar**	0.3 million
16.	*Mexico**	0.2 million
17.	Spain	0.1 million
18.	*Colombia**	0.1 million
19.	*Sudan**	0.1 million

Less than 50,000 hectares

*Honduras**	Romania
*Chile**	Slovakia
Portugal	*Costa Rica**
*Cuba**	*Bangladesh**
Czech Republic	

** Developing countries*



Source: Clive James, 2014.

1.0 million hectares or more of biotech crops, the majority (8 out of 10) are developing countries, with Brazil, Argentina, India, China, Paraguay, Pakistan, South Africa, 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 19, the same as 2013. The three African countries commercializing biotech crops, (South Africa, Burkina Faso and Sudan) are already mega-countries, with Burkina Faso and Sudan both qualifying in only their second year of commercialization. Notably, 15 of the 19 mega-countries are developing countries from Latin America, Asia and Africa. The high proportion of biotech mega-countries in 2014, 19 out of 28 equivalent to 69% 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 19 years.

It is noteworthy, that in absolute hectares, the largest year-over-year growth, by far, was the USA at 3.0 million hectares, followed by Brazil at 1.9 million hectares and Canada at 0.8 million hectares. The top three biotech countries in terms of global share of the million hectares planted globally were USA at 40%, Brazil at 23% and Argentina at 13%.

On 30 October 2013, in a landmark decision, Bangladesh approved the official release of four biotech varieties of insect resistant Bt brinjal/eggplant/aubergine for seed production and initial commercialization. On January 22, 2014, less than 100 days after approval, Bangladesh's Agriculture Minister Matia Chowdhury distributed to farmers Bt brinjal seedlings for commercial planting. Brinjal is a very important vegetable in Bangladesh, where it is grown by about 150,000 very small poor farmers on ~50,000 hectares, in both the winter and summer seasons. Brinjal suffers regular and heavy losses from a very serious insect pest, called the fruit and shoot borer which conventional insecticides cannot control effectively. However, during heavy infestations of the pest, farmers have no option except to attempt control by applying insecticides, sometimes every other day, up to a total of ~80 applications per season, resulting in serious pesticide exposure implications for producers, consumers and the environment. Previous experimental data indicate that Bt brinjal can improve yield by at least 30% and reduce the number and cost of insecticide applications by a massive 70-90%, with a net economic benefit of US$1,868 per hectare; this is a princely sum for some of the poorest farmers in the world in a country where the annual per capita income is only US$700. At the national level, Bt brinjal is estimated to have the capacity to generate a net additional economic benefit of US$200 million per year for the 150,000 brinjal farmers in Bangladesh and consumers will benefit from a cleaner, improved and more affordable food product.

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 fifth year, a commercial biotech flower, the "blue rose" in 2014. 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 2014, five EU countries (Spain, Portugal, Czechia, Romania and Slovakia) continued to plant 143,016 hectares of biotech Bt maize in 2014, equivalent to a ~3% decrease over 2013 at 148,013 hectares; the decrease was principally due to less maize hectarage planted in 2014, particularly in Spain, the country with the largest hectarage. Spain leads the EU countries with the largest Bt maize hectarage of 131,538 hectares, 92% of the EU total 143,016 hectares. Bt maize hectarage was up in three countries Portugal, Romania and Slovakia, and down in two countries Spain and Czechia. The decreases in Bt maize were marginal and associated with several factors, including less total hectares of maize planted, disincentives for some farmers due to bureaucratic and generally onerous reporting of intended plantings of Bt maize, and in some cases a limited seed supply.

Economic benefits of biotech crops

In the latest provisional data, the six principal countries that have gained the most economically from biotech crops, during the first 18 years of commercialization of biotech crops, 1996 to 2013 are, in descending order of magnitude, the USA (US$58.4 billion), Argentina (US$17.5 billion), India (US$16.7 billion), China (US$16.2 billion), Brazil (US$11.8 billion), Canada (US$5.6 billion), and others (US$7.1 billion) for a total of US$133.3 billion.

In 2013 alone, economic benefits globally were US$20.4 billion of which US$10.1 billion was for developing and US$10.3 billion was for industrial countries. The six countries that gained the most economically from biotech crops in 2013 were, in descending order of magnitude, the USA (US$9.2 billion), Brazil (US$3.4 billion), India (US$2.1 billion), Argentina (US$1.9 billion), China (US$1.6 billion), and Canada (US$0.96 billion), and others (US$1.24 billion) for a total of US$20.4 billion. At the time when this Brief went to press, estimates of economic benefits, productivity, landsaving and carbon data are provisional for 1996-2013 and pesticide data is for 1996 to 2012.

Country Chapters

USA

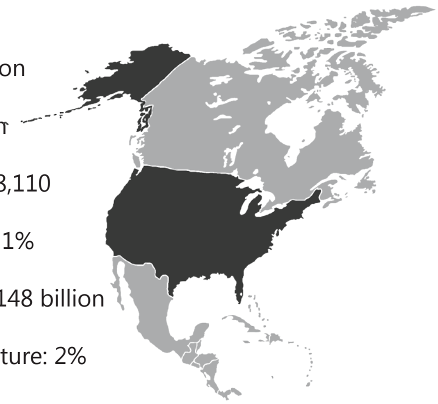
> **In 2014, the USA continued to be the largest producer of biotech crops in the world, with a global market share of ~40%. The USA planted a record hectarage of 73.1 million hectares featuring eight biotech crops (maize, soybean, cotton, canola, sugar beet, alfalfa, papaya and squash) in 2014, up from the 70.1 million hectares in 2013. Importantly, unlike 2013 and the previous four years, when Brazil was the global engine of growth and reported the largest annual gain in biotech crop hectarage (mostly due to a significant increase in biotech soybean hectarage), it was the USA that recorded the largest gain (3 million hectares, equivalent to a 4% growth) in 2014. The USA also leads the world in the deployment of stacked traits; 76% of total maize plantings in the US were stacked, and in cotton it was 78% – the stacked traits offer farmers multiple and significant benefits. In 2014, drought tolerant maize was planted in 275,000 hectares, a 5.5-fold increase from the 50,000 hectares planted by 2,000 farmers in 2013, indicating strong US farmer acceptance of the technology. Impressively, all adoption rates of the principal biotech crops in the USA were up in 2014 compared to 2013: soybean 94% (up from 93% in 2013), maize 93% (up from 90% in 2013) and cotton 96% (up from 90% in 2013) with a very high average, close to optimal adoption of 94%. Given the high rates of adoption, further progress in the US will be achieved through: increases in crop plantings; stacking of multiple traits in the same crop; the introduction of new biotech crops and/or traits. In 2014, the US approved the following two "new" biotech crops for possible planting in 2015; Innate™ potato with lower levels of acrylamide, a potential carcinogen and less wastage due to bruising; and reduced lignin alfalfa event KK179 (HarvXtra™) with higher digestibility and yield. It is provisionally estimated that the USA has enhanced farm income from biotech crops by US$58.4 billion in the first eighteen years of commercialization of biotech crops, 1996 to 2013. This represents 44% of global benefits for the same period; the benefits for 2013 alone were estimated at US$9.2 billion (representing 45% of global benefits in 2013). These are the largest economic gains for any biotech crop country.**

The USA is the leader of the six "founder biotech crop countries", having spearheaded 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 2014 with 73.1 million hectares of biotech crops and a 4% growth rate. USDA estimates (USDA NASS, 2014) indicate that the percentage adoption of the three principal biotech crops were at, or close to, optimal adoption: soybean 94% (up from 93% in 2013), maize 93% (up from 90% in 2013) and cotton 96% (up from 90% in 2013) with a very high average of 94%, biotech sugar beets are at 98.5% adoption and canola at 94%. Total hectares of upland cotton plantings increased by ~8% in 2014, from 4.1 in 2013 to 4.5 million hectares. The total hectarage planted to biotech maize, soybean, cotton, canola, sugar beets, alfalfa, papaya and squash was 73.1 million hectares compared with 70.1 million hectares in 2013.

Total plantings of maize in the USA in 2014 was down by 4% at 37.1 million hectares from 38.5 million hectares in 2013 (NASS USDA, 2014) which is the lowest planted acreage in the US since 2010. The

US hybrid maize seed market is valued at US$12 billion annually and biotech maize continued to be attractive in the USA in 2014 because of increasing global demand for feed, ethanol and strong export sales. The US exports more than 40% of world exports of maize.

USA



Population: 313.1 million

GDP: US$14,991 billion

GDP per Capita: US$48,110

Agriculture as % GDP: 1%

Agricultural GDP: US$148 billion

% employed in agriculture: 2%

Arable Land (AL): 164 million hectares

Ratio of AL/Population*: 2.4

Major crops:
- Maize
- Sugarcane
- Wheat
- Soybean
- Sugar beet
- Canola
- Cotton
- Alfalfa

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

Total area under biotech crops and (%) increase in 2014:
73.1 Million Hectares (4%)

Farm income gain from biotech, 1996-2013: $58.4 billion

*Ratio: % global arable land / % global population

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

In December 21, 2011, the US Department of Agriculture deregulated Monsanto's first generation drought tolerant trait for maize, MON87460, which signaled 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 was extreme to exceptional drought. The drought trait developed by Monsanto in collaboration with BASF Plant Science has led to the first drought tolerant maize (Crop Biotech Update, 6 January 2012). Importantly, in 2013, the USA benefited from the first ever biotech drought tolerant maize which was grown commercially on ~50,000 hectares by about 2,000 farmers. The biotech drought tolerant maize DroughtGard™ with event MON87460 was developed 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 also exhibits improved hydro-efficiency to ensure conservation of soil moisture and reduces yield loss under drought conditions.

In 2014, 275,000 hectares DroughtGard™ maize was planted – equivalent to a large 5.5-fold year-to-year increase in planted hectares between 2013 (at 50,000 hectares) and 2014. This reflects strong US farmer acceptance of the first biotech-derived drought tolerant maize technology to be deployed globally. It is noteworthy that Event MON 87460 was donated by Monsanto to the Water Efficient Maize for Africa (WEMA), a public-private partnership (PPP) designed to deliver the first biotech drought tolerant maize to selected African countries starting 2017. At 93% adoption rate in 2014, the total biotech maize in the US is 34.5 million hectares.

USDA (2014) estimated that the total plantings of soybean in the US in 2014 were 34.3 million hectares, up a substantial 6% or 3.7 million hectares. Hence at 94% adoption rate in 2014, the total biotech soybean in the US is 32.3 million hectares. Total planting of upland cotton at 4.5 million hectares in 2014 was up by ~10% from 4.1 million hectares in 2013. At 96% adoption rate in 2014, the total biotech cotton in the US is 4.3 million hectares.

Canola hectarage in the USA in 2014 was 729,000 hectares, up 528,000 hectares from 2013, with herbicide canola planted at 685,000 or 94% of total canola.

Total hectarage of sugar beet in 2014 was similar to 2013 at ~500,000 hectares. With 98.5% adoption, herbicide tolerant sugar beet covered 479,000 hectares in 2014. Alfalfa is planted as a forage crop and grazed or harvested and fed to animals, and seeded in the spring and the fall.

Alfalfa total hectarage seeded for 2014 is estimated at 1.3 million hectares and the accumulated hectarage was 862,000 hectares of herbicide tolerant canola. 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 up to 8 million hectares.

In 2014, the US approved the following biotech crops for cultivation, probably starting in 2015; Enlist™ Duo for dual mode herbicide tolerance to glyphosate and 2,4-D in soybean and maize; Innate™ potato with lower levels of acrylamide, a potential carcinogen, and less wastage due to bruising; reduced lignin alfalfa event KK179 to be marketed as HarvXtra™ with higher digestibility and yield. More details are provided elsewhere in this Brief. It is noteworthy that recently, Simplot has pioneered this strategy by licensing biotech late blight resistant potato from the John Innes Institute in the UK and developed the late blight resistant potato with low acrylamide potential, reduced black spot bruising and lowered reducing sugars. The company has submitted an application for non regulated status to APHIS, and through an enhanced petition review process, APHIS has already invited public comments on the application.

In 2014, the USA continued to grow more biotech crops (73.1 million hectares) than any other country in the world, equivalent to ~40% of global biotech crop hectarage. Considering the already high level of adoption of biotech crops in the US at an average of approximately 94% or more, the gain of 3 million hectares in 2014, even from high levels in 2013 is a strong vote of confidence by US farmers in biotech crops. In the US, there has been a steady increase every year in the percentage adoption for the major crops which are now very close to optimal with biotech soybean at 94%, cotton at 96% adoption, maize at 93% adoption, canola at 94% and sugar beet at 98.5%.

Stacked (Bt/HT) biotech maize and cotton continued to be the dominant trait in maize and cotton. 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 2014, in descending order of hectarage were: Brazil, Argentina, Canada, South Africa, Australia, the Philippines, Mexico, Uruguay, Chile, Honduras, Paraguay, and Colombia.

Herbicide Tolerant Sugar beet

Sugar beet 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 sugar beet 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 sugar beet 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 sugar beet planted in the USA, equivalent to 257,975 hectares were RR®sugar beet. Farmers welcomed the commercialization of sugar beet and were very pleased with the biotech product, which provided superior weed control, and was more cost-effective and much easier to cultivate than conventional sugar beet. Farmers cited many advantages of RR®sugar beet over conventional including: the number of required cultivations cut by half, with a 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 sugar beet. In 2008, growers became convinced of the value of RR®sugar beet 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®sugar beet was 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 sugar beet planted in the USA in 2009 were devoted to varieties improved through biotechnology. From 2010 to 2014, the total hectarage of sugar beet was the same at approximately 485,000 hectares, of which biotech percentage increased from 95% in 2011 to 98.5% in 2014. During the last couple of years, critics have tried to pursue legal avenues for stopping or restricting planting of RR®sugar beet, but the scientific and farming logic of biotech sugar beet has resisted all the attempts in the courts by the critics. In a landmark decision RR®sugar beet was deregulated by the USDA in July 2012 (USDA, 19 July 2012).

Adoption of RR®sugar beet 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 biotech sugarcane, led by Brazil (~10 million hectares), India (5 million) and China (2 million). The very high level of satisfaction and demand by US and Canadian farmers (see Canada section) for RR®sugar beet 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, improved through biotechnology, has not yet been commercialized. However, significant research is actively under way in Indonesia, 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 Sugar beet Association, opined that ***"Biotech sugar beet seeds arrived just in time to save a struggling industry that is essential to our nation's food security. Sugar from sugar beet 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 Alfalfa and Approval of Low Lignin Alfalfa for Commercialization

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. By 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 significant and it is estimated that the total accumulated hectarage of this herbicide tolerant perennial crop planted from 2011 to 2014 is up to 862,000 hectares. Neither the USDA nor industry publish estimates of adoption for RR alfalfa hence verification from these two sources is not possible.

It is noteworthy that approximately one-third (113 out of 381) of alfalfa farmers surveyed in 2011 reported seeding RR®alfalfa, and a remarkably high of 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, 2013 and 2014 was strong, because of the significant benefits it offers.

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. Gene flow has been studied and 300 meters provides adequate isolation between conventional and biotech alfalfa and 500 meters for seed crops. 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 10 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.

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. 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. Monsanto developed the biotech RR alfalfa in partnership with Forage Genetics International. In 2014, biotech low-lignin alfalfa event KK179 was approved for cultivation in the US. The product, which has less lignin, has higher digestibility, and it is claimed to also offer a 15 to 20% increase in yield and hence is likely to be in high demand by farmers.

Biotech Papaya Resistant to PRSV

Papaya ring spot virus (PRSV) resistant papaya was developed by Cornell University (USA) and University of Hawaii in 1997 and commercialized immediately in the US since 1998, sixteen years ago. In less than four years, papaya production recovered and Hawaii has started exporting its biotech papayas to Canada and in Japan – in a landmark decision, Japan approved the import of biotech papaya from the US in 2011, for consumption as fresh fruit/food. 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). Japan has been continuously importing eight approved biotech products including: soybean, maize, potato, rape seed, cotton seed, alfalfa, sugar beet and papaya. Although Hawaiian GMO papayas are resistant only to Hawaiian PRSV, the successful development in Hawaii inspired other papaya cultivating countries to develop virus resistant papayas for their local markets. Resistant papaya varieties are now being developed in Brazil, Taiwan, Jamaica, Indonesia, Malaysia, Thailand, Venezuela, Australia and the Philippines. In the US, there are a nominal 1,000 hectares planted to virus-resistant papaya and 1,000 hectares with virus resistant squash.

Recently, a proposal to ban biotech papaya has been submitted to the Maui County Council in Hawaii. The US Environmental Protection Agency relayed to the Council that there are no health problems linked with consumption of biotech papaya rainbow. Chris Wozniak of EPA emphasized that there is no difference between eating rainbow papaya and a papaya with the virus, which is prevalent (Crop Biotech Update, 9 July 2014).

Stewardship for Insect Resistance

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 has reported that, 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 2012/13. Resistance to rootworm has also been detected in other countries, Argentina and Brazil, as was documented by Gassman et al (2014). Furthermore, the field-evolved resistance by western corn rootworm was observed in **multiple *Bacillus thuringiensis* toxins in biotech maize crops. It also confirms that IR GM crops producing less than a high dose of toxin against target pests may select for resistance rapidly.**

Managing resistance in insect pests will always be a challenge but studies in the University of Arizona led by Tabashnik concluded that ***"the picture is rosier than expected"*** (Tabashnik et al. 2008). The study reported that in cases where resistance has developed, it is highly localized. ***"For example, western corn root worm may withstand one toxin in several farms in the mid-west but not all toxins and not in all regions of the country or the world."*** Whereas refuge areas do not eliminate resistant pests, they are very effective in controlling large infestations. Experience to-date with the refuge in the bag (RIB) looks very promising and companies may well decide that it is the only realistic option of effectively implementing a refuge system, particularly in developing countries where monitoring implementation of a refuge system is very often difficult or impractical. It is not surprising that experience to-date has demonstrated that countries which have strictly implemented the refuge system, like Australia, have not had pest outbreaks whereas countries with lax systems have witnessed resistance breakdowns. The RIB system is self-protective and allows farmers, even in developing countries, to fully benefit from an effective resistant management scheme, and preclude serious resistance breakdowns leading to significant crop losses. Various versions of Bt genes and gene combination for insect resistance are now in the pipeline for corn, soybean and cotton.

Developments in Biotech Wheat

The US wheat hectarage has been found to decline sharply as compared with biotech maize and soybean. In 1996, 28 million hectares of wheat were planted in the US which declined by 18% or 22 million hectares in 2012, and has remained at the low level in 2014. Maize hectares increased by 10 million to reach 39 million between 1996 and 2012, whilst soybean increased by 6 million to reach 31 million hectares (Capitalpress.com. 2013) – in 2014 maize hectares in the US were at 37.0 million and soybean at a record 3.3 million hectares. Wheat farmers reported that the decline in wheat is due to its non-competitiveness compared with biotech maize and soybean. Their views were supported by the returns per hectare for the three crops estimated by USDA. Return per hectare was US$1,213 for maize, US$825 for soybean and only US$355 for wheat – three times less than maize and twice less than soybean. Monsanto initiated research on biotech wheat in 1997 but stopped in 2004 because of grower concerns about consumer acceptance in domestic and export markets. However, five year later in 2009 the same wheat industry stakeholders became worried about wheat losing market share to biotech maize and soybean and reached out to Monsanto and other biotech companies to resume work on biotech wheat stating that ***"it is in all our best interests to introduce biotech wheat varieties in a coordinated fashion to minimize market disruptions and shorten the period of adjustment."***

To this end, an International Wheat Yield Partnership (IWYP), a group that aims to increase wheat yields by 50 percent in 2034, was launched at the "Borlaug Summit on Wheat for Food Security" in Ciudad Obregón, Mexico in March 2014. The program brought together research funders, international aid agencies, foundations, companies, and major wheat research organizations, to serve as unique vehicle for new discoveries and their speedy incorporation into wheat crops grown in different parts of the world. It also aims to stimulate new research and make scientific discoveries available to farmers in developing and industrial countries. The partnership's initiators include the UK's Biotechnology and Biological Sciences Research Council (BBSRC), the International Maize and Wheat Improvement Center (CIMMYT), the Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food of Mexico (SAGARPA) and the United States Agency for International Development (USAID) (Crop Biotech Update, 26 March 2014).

Similarly, sixteen organizations from Australia, Canada, and the U.S. released a statement confirming their support for the future commercialization of biotech wheat. In 2009, there were only 9 organizations of farmers and millers who signed the agreement and by 2014, 7 more joined the wheat commitment. The new organizations include American Farm Bureau Federation and the National Farmers Union (Crop Biotech Update, 11 June 2014).

According to World Food Prize Laureate Robert Fraley, development of herbicide tolerant wheat is making a good progress. He said that the grain industry and the wheat industry have remained interested on biotech advances because a wheat farmer is also a grower of corn and soybean and so they understand the benefits of the technology. Although their research is making progress, the commercialization of biotech wheat is still a number of years away (Crop Biotech Update, 15 January 2014).

Traits being developed in biotech wheat include herbicide tolerance, disease (*Fusarium*, which produces a mycotoxin) and insect resistance, drought tolerance, nitrogen use efficiency, quality traits such as anti sprouting and productivity. It is estimated that the first biotech wheat will be ready for commercialization in about ten years from now. Wheat biotech projects are underway in many countries in the public and private sector including Australia, China and USA. To expedite improvement of wheat through biotechnology, the genetic blue print of bread wheat genome was released in 2014 by the International Wheat Genome Sequencing Consortium (IWGSC). The consortium has established the first reference sequence for the largest chromosome, 3B, which could serve as a template for sequencing the remaining chromosomes. With a chromosome-based full sequence in hand, plant breeders now have high quality tools at their disposal to speed up breeding programs and identify how genes control complex traits such as yield, grain quality, disease, pest resistance, or abiotic stress tolerance. They will be able to produce a new generation of wheat varieties with higher yields and improved sustainability to meet the demands of a growing world population in a changing environment (Crop Biotech Update, 23 July 2014).

Benefits from Biotech Crops in the USA

In the most recent global study on the benefits from biotech crops, Brookes and Barfoot (2015, Forthcoming) provided a provisional estimate that USA has enhanced farm income from biotech crops by US$58.4 billion in the first eighteen years of commercialization of biotech crops 1996 to 2013. This represents 44% of global benefits for the same period, and the benefits for 2013 alone are estimated at US$9.2 billion (representing 45% of global benefits in 2013). These are the largest gains for any biotech crop country.

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 was published by the US National Research Council (2010) (an organization related to the National US Academy of Sciences) in April 2010 on ***"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."***

Biotech/GM American Chestnut Trees

American chestnut (*Castanea dentata*) is a native keystone species that was nearly eradicated by chestnut blight caused by the fungal pathogen, *Cryphonectria parasitica*. The fungus killed the chestnut tree by secreting oxalic acid but this can be detoxified by an enzyme, oxalate oxidase, found in wheat. A new approach to producing American chestnut trees with enhanced blight resistance is through *Agrobacterium*-mediated transformation. The transgenic American chestnut 'Darling4' which expresses a wheat *oxalate oxidase* gene exhibited an intermediate blight resistance. It was found to be more resistant than American chestnut but less resistant to Chinese chestnut (*Castanea mollissima*), the source of the resistance genes. Enhanced resistance was first observed in an assay of young chestnuts grown indoors.

Field trials to test 800 GM chestnuts with various combinations of the 6 genes from Chinese chestnuts and the gene from wheat were conducted to determine whether resistance to the fungus has been conferred. It was then confirmed with traditional stem inoculations on field-grown trees. Initial non-destructive tests on samplings have already established that the required genes have been transferred and the 3 year field trial will establish if resistance in adult trees is functional. Pollen from 'Darling4' were also used to produce transgenic T1 seedlings that expressed the enhanced resistance trait. This is vital for propagation and development of transgenics since outcrossed transgenic seedlings have several advantages over tissue-cultured plantlets. These advantages include increased genetic diversity and faster initial growth. If successful, the decision to release the GM chestnuts into wild forests will be made – it would require a submission requesting approval to release the GM trees following the usual process. The event is unique in that it offers, for the first time, the use of GM to confer resistance on natural forests, rather than commercial tree plantations, such as poplar modified with the Bt gene, to confer resistance to insect pests (Crop Biotech Update, 15 May 2013; 14 May 2014).

Political Will and Support for Biotech Crops in the US

President Obama joined in celebrating Dr. Norman Borlaug's centennial celebration in the US Capitol, and his passion for feeding the hungry through biotechnology with a letter read by Julie Borlaug. He said, ***"I share his belief that investment in enhanced biotechnology is an essential component of the solution to some of our planet's most pressing agricultural problems... I will continue to work with the Department of Agriculture and others to explore innovative solutions to address food security challenges and mitigate the effects of climate change."***

Julie Borlaug, Assistant Director for External Relations at the Norman Borlaug Institute for International Agriculture said ***"This is a huge endorsement of the importance of agriculture research and biotechnology. My grandfather would have been grateful and appreciative of the president's focus on agriculture and climate change in an effort to feed the 9 billion people expected to live on this planet by 2050"*** (Crop Biotech Update, 16 April 2014). President Obama has been an advocate of biotechnology. 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 (Crop Biotech Update, 27 January 2012).

Former US Secretary of State Hillary Rodham Clinton has adamantly voiced support for genetically modified organisms in a 65-minute keynote address and moderated discussion during the Biotechnology Industry Organization's (BIO) annual conference in San Diego, California. She cited that as U.S. Secretary of State she was a major proponent of genetically engineered seeds, especially drought resistant ones, and added that one of her official programs was to encourage people in Africa to use GMOs to grow their own food. ***"I stand in favor of using seeds and products that have a proven track record. There's a big gap between the facts and what the perceptions are"*** (Crop Biotech Update, 2 July 2014).

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. 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 Bill and Melinda Gates Foundation (BMGF) has strengthened its support for GM crops. In 2012, BMGF 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.

GM Food Labeling

Following the defeat of Washington State's Initiative 522 to require labeling of GM products on the 5 November 2013 poll and the California's Proposition 37 on 6 November 2012, a similar poll was conducted in the New Hampshire Environment and Agriculture Committee in January 2014. The House of Representatives has voted down its version of the GMO bill by 185-162. In 2013, Connecticut was the first state to adopt a GMO Law. Maine Governor Paul Le Page signed the GM labeling Law LD718 in early January 2014 – both states requiring contiguous states to pass similar Law for effectivity. The state of Vermont has passed the Vermont Act 120 in April 2014, signed in May 2014 and will be effective on the first of July 2016. On November 8, 2014 Colorado State Proposition 105, a ballot initiative mandating labels for genetically engineered foods sold at retail failed by a big margin: 66% voting against versus 34% in favor. It was the second year in a row that Colorado opponents of genetic engineering tried and failed to impose new restrictions on the technology. On November 11, the state of Oregon released the results of the polls conducted on November 4 on a similar Bill, with 50.5% voting against versus 49.5% in favor.

A study by Alston and Sumner (2012) estimated that, if passed, the cost of implementing Proposition 37 for GM food labeling in California 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.

The International Food Information Council (IFIC) commissioned a study involving 1,000 adults to find out if they approve of the U.S. Food and Drugs Administration's policy for labeling GM foods. Results showed that 63 percent of U.S. adults consistently approve the policy over the past six years. However, IFIC also acknowledges that opposition to the policy is also increasing over the years. The 2013 study results showed that 19 percent are against the policy, up from 14 percent in 2012, and 13 percent in 2008. "The survey has consistently shown that, when made aware of the health and agronomic benefits of food biotechnology, most Americans are receptive, indicating that accurate information about the technology is important to promoting informed food choices," according to IFIC, which has surveyed consumer perceptions about genetic engineering since 1998 (Crop Biotech Update, 4 June 2014).

An analysis of GMO labeling costs by two Cornell University scientists estimated the costs at US$500 per family of 4 each year. The GMO food labeling law requires information if a product was produced by a GMO and not what type of genetic change has been made to the organism. It will not provide information about the composition or the nutritional properties of the product, nor the amount of GMO product in the food. If labeling is accepted, anti-GMO organizations will make life miserable for firms selling GMO-containing foods. Firms will reformulate their products, but will have a hard time sourcing substitutes at reasonable prices. Hence, the main purposes of GMO labeling are just to satisfy "consumer curiosity" and to increase sales of the organic food industry, which funded the initiative. The costs will be huge, the benefits to consumers small, and the effort needed will be immense. Studies by the National Academy of Sciences and the American Medical Association reveal that there is no science-based reason to subject GM foods for mandatory labeling since they have already been deemed safe (Daily Camera Opinion, 19 Sept 2014)

The Council of the American Phytopathological Society (APS) has refined its position on biotechnology as three pioneers of agricultural biotechnology received the World Food Prize in 2013. The APS is the world's largest organization of plant health scientists, representing almost 5,000 members from 90 different countries. Citing the enormous potential benefits for management of plant diseases offered by this technology, APS reiterated its support and opposed mandatory labeling of food derived from genetically modified (GM) plants. George Abawi, APS President said ***"Biotechnology today is a valuable tool for improving plant health, food and feed safety, and sustainable gains in plant productivity. As has been discussed this week during the Borlaug Summit and the World Food Prize, biotechnology will continue to be an extremely important part of the toolbox for managing plant health."*** While strongly supporting transparent science-based regulation of agricultural products, APS has long opposed regulating food, feed, and fiber products solely on the basis of the particular technology used to create these products. Abawi added, ***"Current scientific evidence supports the conclusion that GM plants pose no greater safety risk than traditionally bred plants. Labeling GM could be very confusing to consumers and could reduce the availability and use of this technology for the management of plant diseases"*** (Crop Biotech Update, 23 October 2013).

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. 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"*** (APHIS, 2011).

In 2014, the American Soybean Association teamed up with the Illinois Soybean Association (ISA) to organize a forum that aimed to communicate the need for a quicker and more science-based process for biotech crop approval. The event, held in Washington, D.C., was attended by more than 100 farmers, researchers and agricultural group leaders. ***"It is critical that agriculture let policymakers and regulators in Washington know how much farmers need biotechnology to sustainably produce food for the world's population,"*** soybean grower and ISA chairman Bill Raben said. Prof. Robert Paalberg, a public policy professor at Harvard University and an adviser to different food and agriculture organizations worldwide, stressed that the state of worldwide regulation deprives people of food by preventing use of biotechnology by farmers in poorer countries who are growing more food crops (Crop Biotech Update, 20 August 2014).

Farmer Experience

A Nebraska farmer and chairman of the American Soybean Association Steve Wellman shared his views of Biotech crops and opined that biotech crops allowed him to gain from both environmental and production benefits (Crop Biotech Update 2 May, 2013). He first saw biotech crops years ago when he had on-farm trials of the Roundup Ready trait before it was commercialized – he could immediately see the benefits of the weed control. ***"It was easy to identify how it was going to play a role in making that transition toward no-till production."*** Wellman believes that ***"biotechnology is the base that drove a lot of the improvements in the U.S. and the ability to utilize conservation tillage."*** The effort to sustainably increase production on only current land is necessary to meet increasing global demand due to a growing population and increased income. More specifically on corn, between 2000 and 2030 it is predicted that demand will increase 76% and 125% for soybeans and that will be another 70 to 80 million metric tons of soybeans required per year for the next decade. Finally, he said that ***"to me, biotechnology, increasing production agriculture and sustainable agriculture go together. I believe that biotechnology has been the trigger for our advancements, and it will be a future to production agriculture to continue to be sustainable and to improve upon that."***

Duane Grant, chairman of the Snake River Sugar Company, a national biotech spokesman for the U.S. sugar industry and a farmer from Rupert, Idaho said that the U.S. sugar beet industry is essentially 100 percent biotech. GMO sugar beets saved the industry, which accounts for 40 percent of U.S. sugar consumption. In the 2014 Idaho Hay and Forage Conference on 28 February 2014, Mr. Grant reiterated the need to be stewards of biotechnology because it brings real value and it works. Stewardship of biotechnology in agriculture goes beyond sugar beets, and farmers, agricultural organizations and biotech providers need to embrace all approved technologies. Stewardship means leading the public, regulatory and commercial discussion, and farmers should be willing to join. It also means using best management practices in GMO crop production, knowing customers and giving them choices. Farmers are adopting biotechnology because it works. It increases yields and decreases the use and cost of pesticides. Not only are growers producing safe food with better yields, they're sharing the benefits of biotechnology with biotech firms, seed dealers, and consumers, who capture a large majority of the benefit, he said (Truth about Trade, 5 March 2014).

Members of the new trade organization, the U.S. Farmers and Ranchers Alliance, in a press conference on 18 September 2014, with various California media opined that GMOs as the solution to threats to the global food supply. They emphasized the GMOs' role in agriculture as well as increasing the food supply and lowering costs to consumers. Don Cameron, vice president and general manager of Terranova Ranch in Helm, California, noted that they used GMO crops where they so fit on their farm. They also look at GM crops as water-saving devices since Roundup Ready crops can help get rid of competing weeds, thus saving water. The panel of experts for the media tour included Cameron, plant molecular biologist Bob Goldberg from UCLA, Illinois corn and soybean farmer Katie Pratt and DuPont Pioneer strategist Jim Gaffney. The group was formed to give all the "voices of agriculture" a "voice" to inform consumers about how food is grown in the US. The tour comes as GMOs are increasingly under fire in the West. In Oregon, voters in November will consider Measure 92, requiring GM labelling. In California, a bill requiring any agricultural commodity produced with GM to be labeled was voted down in a committee. The panelists say they hope their efforts will ease consumers' concerns about biotech crops even if they're required to be labeled. "As farmers, we definitely see the benefits in using this technology," Pratt said (Capital Press, 18 September 2014).

BRAZIL

In the 2014 crop season, Brazil's total biotech crop hectares of soybean, maize and cotton was estimated at ~42.2 million hectares, an increase of 4.6%, from 2013, or 1.9 million hectares; Brazil's 42.2 million hectares of biotech crops in 2014 represents 23% of the global hectarage of 181.5 million hectares. In 2014, the total biotech crop hectares in Brazil of 42.2 million hectares comprised: 29.1 million hectares of biotech soybean; 12.5 million hectares of biotech maize (summer and winter maize); and 0.6 million hectares of biotech cotton. The total planted area of these three crops in Brazil was estimated at ~47.3 million hectares of which ~42.2 million hectares or ~89.2% was biotech. Brazil retained its #2, world ranking after the US (which is the largest country hectarage in the world with 73.1 million hectares), representing 40% of the global hectarage of 181.5 million hectares. In Brazil, biotech soybean still occupies the highest hectarage with 29.1 million hectares, with a year-to-year increase of ~2.1 million hectares or 7.9% and a 93.2% adoption rate of the 31.2 million hectares national soybean crop grown in 2014/15. The second most important biotech crop in Brazil was GM maize for a total of 12.5 million hectares (summer 4.8 million hectares and winter 7.7 million hectares), a decrease of ~2.9%

from 2013, due to a reduction in the total maize area planted. Biotech cotton was the third biotech crop in Brazil, estimated to occupy 0.6 million hectares in 2014/15, a 65.1% adoption rate of the total of 0.9 million hectares planted with cotton in Brazil in 2014. In 2014/15 biotech cotton increased by 25.1% over 2013. All three categories of events IR, HT, and the stacked IR/HT were deployed in all three crops. Intacta™, the new IR/HT soybean was first planted in 2013/14, and in its second season, 2014/15, it reached an estimated area of ~5.2 million hectares, an increase of 136% compared with the 2.2 million hectares in 2013. The home-grown virus-resistant bean, approved for planting in 2011, is completing variety registration trials and is expected to be commercialized in early 2016, with two varieties of the "carioquinha" type. The herbicide (imidazolinone) tolerant soybean Cultivance™ jointly developed by EMBRAPA and BASF is expected to be commercialized in 2016, pending import approval by the EU. The economic benefits to Brazil from biotech crops, estimated by Celeres for the 17 year period (1996/97 to 2012/13) was US$24.8 billion and US$6.3 billion for 2013 alone. A different annual global study of benefits from biotech crops covering the 10 year period 2003 to 2013, using a provisional data concluded that Brazil gained US$11.8 billion and US$3.4 for 2013 alone (Brookes and Barfoot 2015, Forthcoming).

BRAZIL

Population: 196.7 million

GDP: US$2,477 billion

GDP per Capita: US$12,590

Agriculture as % GDP: 5%

Agricultural GDP: US$123.8 billion

% employed in agriculture: 17%

Arable Land (AL): 70.6 million hectares

Ratio of AL/Population*: 1.7

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

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

Total area under biotech crops and (%) increase in 2014:
42.2 Million Hectares (+5%)

Farm income gain from biotech, 2003-2013: US$11.8 billion

*Ratio: % global arable land / % global population

The first crop estimate for 2014 (2014/2015/ by CONAB (the Brazilian agency for crop surveys), projects an increase of grain planted to a record area of 58.3 million hectares; an increase of 2.5% in planted area over 2013/2014. Soybean crop is the leader in hectarage at 31.8 million hectares, an increase of 5.5% over the last season. Between 2005/06 and 2014/15, the harvested crop area in Brazil increased from 47.3 million hectares to 58.3 million hectares, an annual growth rate of 2.1%. The largest growth during this 10 year period was the winter maize crop, 10.6% per year increasing from 3.3 million hectares to 9.2 million hectares.

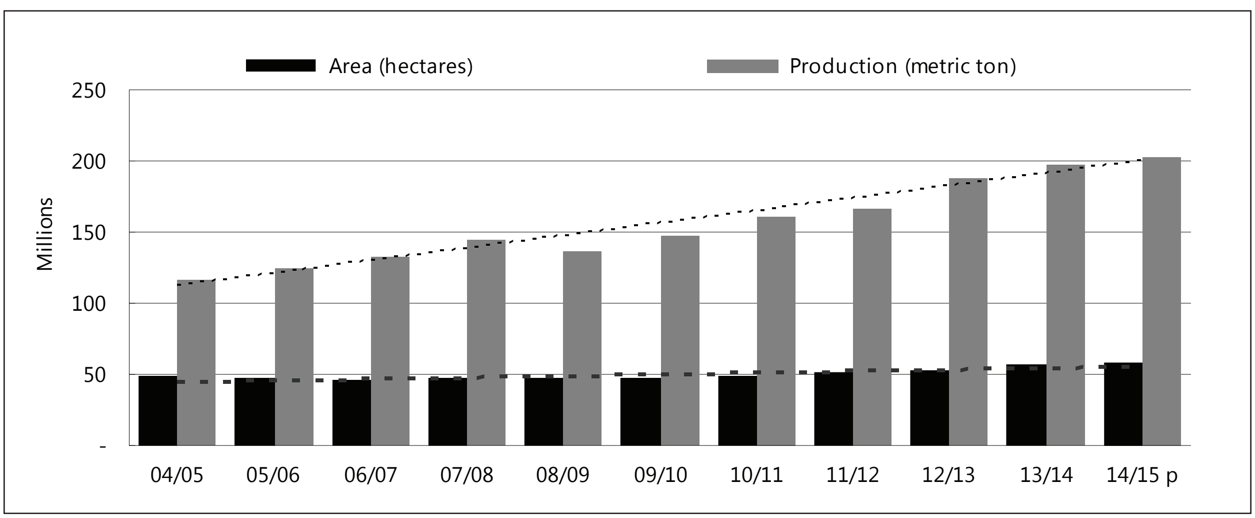
According to a CONAB prediction, total Brazilian grain production will reach 203.3 million tons, in

2014/15, an increase of 3.1% compared to the 2013/14 crop season (Figure 5). For the ten year period, 2005/06 to 2014/15, grain production increased by 5.0% per year as a result of consistent gains in yield and crop management improvement; crop yield increased, at an annual growth rate of 2.9%. 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, has also protected the domestic economy from the global financial crises during the last couple of years.

During this ten year period, the crops that provided the biggest increase in hectarage were soybean (+9.5 million ha), and winter maize (+5.8 million ha) which are normally cultivated in a soybean/maize cropping system: soybean crop in the summer season and maize in the winter season as a cover crop. The crops that suffered a decrease in hectarage during the same period were summer maize at -3.1 million ha, edible beans (-0.94 million ha), and rice (-0.54 million hectares).

In the 2014 crop season, Brazil's total biotech crop hectarage for soybean, maize and cotton was estimated at ~42.2 million hectares, an increase of 4.6% compared to 2013, or 1.9 million hectares. The total biotech crop hectarage includes 29.1 million hectares of soybean, 12.5 million hectares of maize (summer and winter maize) and 0.6 million hectares of cotton. The total planted area of these three crops in Brazil was estimated at ~47.3 million hectares of which ~42.2 million hectares or ~89.2% was biotech (Table 4) Brazil is still ranked as #2 in global biotech area (USA is #1 with a biotech crop hectarage of 73.1 million hectares), which accounts for ~40% (similar to 2013) of the global biotech crop hectarage of 181.5 million hectares. Biotech soybean is still leading and the most important biotech crop, increasing by ~2.1 million hectares or 7.9% from 2013, occupying 93.2% of the 31.2 million hectares of the national soybean crop grown in 2014/15. The 29.1 million hectares was comprised of

Figure 5. Grain Production in Brazil



Source: CONAB | Elaboration: CÉLERES®.

76.7% HT and 16.5% IR/HT with a balance of 6.8% conventional (Table 5). The highest adoption rate, by region, was in the South region with 94.7% (within which Rio Grande do Sul has the highest at 99.2% adoption, followed by the Southeast at 94.3% (São Paulo state has the highest adoption, 95.3%) and the Midwest at 94.2% (Goiás state had the highest adoption, at 98.7%).

The second most important biotech crop in Brazil is GM maize, a total of 12.5 million hectares (Table 6) for both summer (4.8 million hectares, Table 7) and winter (7.7 million hectares, Table 8), a decrease of ~2.9% from 2013, due to a total maize area reduction. In Brazil, summer and winter maize crops are discussed separately, because of the many differences in the management of the two crops which are cultivated during different seasons. The details for the two crops can be viewed in Tables 7 and 8. Of the 6.64 million hectares of summer maize (Table 7), 72.6% are biotech, of which 54.0% is IR/HT, 15.7% is IR and 3% is HT alone. The highest adoption, by region, is in the Southeast at 90.2% (Minas Gerais state has the highest adoption rate of 90.3%), followed by the South at 89.9% (Paraná state has the highest adoption rate of 91.6%) and Midwest at 89.7% (Goiás has the highest adoption rate of 91%). On the other hand, winter maize (also referred to as "second season maize crop") occupies a bigger hectarage than summer maize at 8.5 million hectares, and biotech winter maize is responsible for 7.7 million hectares or 90%, of which 44.7% is the stacked product IR/HT, 40.5% is IR and 4.8% as herbicide tolerance alone (Table 8). The highest adoption, by region, is in the South (only Paraná state) at 95.6%, followed by the Midwest at 91.7% (Mato Grosso state at 92.7%) and Southeast (Minas Gerais and São Paulo states at 86.7%).

Genetically modified cotton (Table 9) is the crop with the least hectarage in Brazil in 2014; it is estimated that it will be planted on 0.6 million hectares in 2014/15, 65.5% of the 0.9 million total cotton hectares planted in 2014. In comparison with 2013, biotech cotton will increase by 25.1% in 2014. Of these 0.6 million hectares of biotech cotton, 31.2% is IR, 23.6% is HT and 10.3% is the stacked trait, IR/HT. The highest adoption, by region is in the Midwest at 67.6%, followed by the Southeast at 65.2% and Northeast with 61.4%.

In summary, the collective hectares for all three biotech crops in Brazil in 2014/15 was 42.2 million hectares equivalent to 89.2% adoption; more specifically GM soybean adoption was 93.2%; GM summer maize adoption was 72.6%; GM winter maize was 90.0% and GM cotton adoption was 65.1% (Figure 6).

The most adopted biotech trait in 2014, by far, is herbicide tolerance (HT), with 24.7 million hectares, with a decrease of 2.7% compared to 2013/14, due to substitution with the stacked IR/HT soybean. The stacked gene technology (IR/HT) is ranked as second, with 12.6 million hectares, a growth of 54% compared to the last season, 2013. Lastly, the insect resistance trait (IR) with 4.8 million hectares had a 28.3% reduction compared to 2013 (Figure 7). The use of single trait technology is decreasing fast in favor of the stacked traits, for all three crops, with a considerable contribution from IR/HT soybean commercialization. It is clear that farmers prefer the stacked traits over the single traits because of the bigger benefits that stacks offer.

The evolution of the biotech adoption rate in the three crops: cotton, maize and soybean from the initial year of approved planting to 2014, is presented in Figure 8 with near optimal adoption for soybean and maize.

Table 4. Biotech Crop Adoption in Brazil

	Planted Area (million hectares)	Adoption rate (% of total area)				Biotech Area (million hectares)			
		IR	HT	IR/HT	Total	IR	HT	IR/HT	Total
NORTH	**1.76**	**1.7%**	**44.8%**	**11.6%**	**58.0%**	**0.03**	**0.79**	**0.20**	**1.02**
NORTHEAST	**5.60**	**8.2%**	**38.0%**	**24.8%**	**71.1%**	**0.46**	**2.13**	**1.39**	**3.98**
Maranhão	1.38	8.9%	40.1%	30.2%	79.2%	0.12	0.55	0.42	1.10
Piauí	1.10	6.2%	41.3%	29.2%	76.7%	0.07	0.46	0.32	0.85
Bahia	2.29	11.2%	48.6%	27.3%	87.1%	0.26	1.11	0.62	2.00
SOUTHEAST	**4.28**	**15.2%**	**39.6%**	**36.9%**	**91.6%**	**0.65**	**1.69**	**1.58**	**3.92**
Minas Gerais	2.61	14.1%	41.3%	36.3%	91.7%	0.37	1.08	0.95	2.39
São Paulo	1.64	16.7%	37.5%	37.5%	91.7%	0.27	0.61	0.62	1.50
SOUTH	**14.84**	**8.0%**	**58.3%**	**27.8%**	**94.1%**	**1.19**	**8.64**	**4.13**	**13.97**
Paraná	7.76	13.0%	47.9%	30.6%	91.4%	1.01	3.72	2.37	7.10
Santa Catarina	1.06	5.7%	47.8%	41.1%	94.6%	0.06	0.50	0.43	1.00
Rio Grande do Sul	6.03	2.1%	73.4%	22.0%	97.5%	0.13	4.42	1.32	5.87
MIDWEST	**20.79**	**11.8%**	**55.2%**	**25.7%**	**92.7%**	**2.45**	**11.49**	**5.35**	**19.28**
Mato Grosso	12.44	11.5%	55.6%	24.2%	91.2%	1.43	6.91	3.01	11.35
Mato Grosso do Sul	3.81	16.1%	49.1%	28.2%	93.5%	0.61	1.87	1.08	3.56
Goiás	4.42	8.9%	60.0%	27.3%	96.3%	0.39	2.65	1.21	4.25
Distrito Federal	0.13	10.9%	42.3%	42.2%	95.4%	0.01	0.05	0.05	0.12
N/NE	**7.36**	**6.7%**	**39.6%**	**21.7%**	**67.9%**	**0.49**	**2.92**	**1.59**	**5.00**
C-SOUTH	**39.91**	**10.8%**	**54.7%**	**27.7%**	**93.1%**	**4.29**	**21.82**	**11.05**	**37.17**
BRAZIL	**47.27**	**10.1%**	**52.3%**	**26.8%**	**89.2%**	**4.78**	**24.74**	**12.65**	**42.17**

Source: Céleres®. *Updated in 7 August 2014

Table 5. Biotech Soybean Adoption in Brazil

	Planted Area (million hectares)	Yield (t/ha)	Production (million t)	Adoption rate (% of total area)				Biotech Area (million hectares)			
				IR	HT	IR/HT	Total	IR	HT	IR/HT	Total
NORTH	**1.21**	**3.11**	**3.75**		**64.7%**	**12.3%**	**77.0%**		**0.78**	**0.15**	**0.93**
NORTHEAST	**2.82**	**2.95**	**8.32**		**71.4%**	**17.6%**	**89.0%**		**2.01**	**0.50**	**2.51**
Maranhão	0.80	3.06	2.43		67.7%	16.3%	83.9%		0.54	0.13	0.67
Piauí	0.67	2.80	1.86		66.1%	13.7%	79.8%		0.44	0.09	0.53
Bahia	1.36	2.96	4.02		76.1%	20.3%	96.4%		1.04	0.28	1.31
SOUTHEAST	**2.13**	**3.05**	**6.49**		**75.3%**	**19.0%**	**94.3%**		**1.60**	**0.40**	**2.00**
Minas Gerais	1.38	3.13	4.32		74.4%	19.2%	93.7%		1.03	0.27	1.29
São Paulo	0.75	2.91	2.17		76.9%	18.4%	95.3%		0.57	0.14	0.71
SOUTH	**10.71**	**2.76**	**29.59**		**79.0%**	**15.6%**	**94.7%**		**8.46**	**1.67**	**10.13**
Paraná	5.10	3.03	15.47		70.4%	19.4%	89.8%		3.59	0.99	4.58
Santa Catarina	0.58	2.94	1.70		83.8%	14.9%	98.7%		0.49	0.09	0.57
Rio Grande do Sul	5.03	2.47	12.42		87.2%	11.9%	99.2%		4.38	0.60	4.98
MIDWEST	**14.33**	**3.01**	**43.20**		**77.2%**	**16.9%**	**94.2%**		**11.07**	**2.43**	**13.50**
Mato Grosso	8.77	3.08	26.99		75.8%	16.4%	92.1%		6.64	1.43	8.08
Mato Grosso do Sul	2.27	2.74	6.20		78.9%	16.6%	95.5%		1.79	0.38	2.16
Goiás	3.23	3.02	9.77		80.1%	18.6%	98.7%		2.59	0.60	3.19
Distrito Federal	0.07	3.36	0.24		73.2%	26.3%	99.4%		0.05	0.02	0.07
N/NE	**4.03**	**3.00**	**12.07**		**69.4%**	**16.0%**	**85.4%**		**2.79**	**0.65**	**3.44**
C-SOUTH	**27.16**	**2.92**	**79.28**		**77.8%**	**16.6%**	**94.4%**		**21.13**	**4.50**	**25.63**
BRAZIL	**31.19**	**2.93**	**91.35**		**76.7%**	**16.5%**	**93.2%**		**23.92**	**5.15**	**29.07**

Source: Céleres®. *Updated in 7 August 2014

Table 6. Biotech Maize Adoption in Brazil, Summer + Winter Seasons

	Planted Area (million hectares)	Yield (t/ha)	Production (million t)	Adoption rate (% of total area)				Biotech Area (million hectares)			
				IR	HT	IR/HT	Total	IR	HT	IR/HT	Total
NORTH	**0.54**	**3.14**	**1.70**	**5.0%**	**1.0%**	**9.9%**	**15.9%**	**0.03**	**0.01**	**0.05**	**0.09**
NORTHEAST	**2.45**	**2.49**	**6.12**	**15.0%**	**2.1%**	**34.6%**	**51.8%**	**0.37**	**0.05**	**0.85**	**1.27**
Maranhão	0.57	2.75	1.56	20.7%	2.4%	50.3%	73.4%	0.12	0.01	0.29	0.42
Piauí	0.42	2.41	1.02	15.4%	3.2%	54.1%	72.7%	0.07	0.01	0.23	0.31
Bahia	0.64	3.73	2.39	26.9%	3.2%	48.4%	78.6%	0.17	0.02	0.31	0.50
SOUTHEAST	**2.13**	**6.53**	**13.89**	**30.1%**	**4.1%**	**55.1%**	**89.3%**	**0.64**	**0.09**	**1.17**	**1.90**
Minas Gerais	1.21	6.92	8.38	29.7%	3.9%	56.1%	89.7%	0.36	0.05	0.68	1.09
São Paulo	0.89	6.11	5.43	30.5%	4.5%	53.8%	88.8%	0.27	0.04	0.48	0.79
SOUTH	**4.13**	**6.47**	**26.75**	**28.9%**	**4.4%**	**59.4%**	**92.7%**	**1.19**	**0.18**	**2.45**	**3.83**
Paraná	2.66	6.76	17.99	37.9%	4.8%	52.0%	94.6%	1.01	0.13	1.38	2.52
Santa Catarina	0.48	7.27	3.46	12.7%	3.8%	73.1%	89.6%	0.06	0.02	0.35	0.43
Rio Grande do Sul	1.00	5.31	5.31	12.7%	3.8%	72.5%	88.9%	0.13	0.04	0.72	0.89
MIDWEST	**5.93**	**6.19**	**36.68**	**38.4%**	**4.7%**	**48.5%**	**91.5%**	**2.27**	**0.28**	**2.87**	**5.42**
Mato Grosso	3.22	6.43	20.73	39.8%	4.7%	47.9%	92.5%	1.28	0.15	1.55	2.98
Mato Grosso do Sul	1.51	5.05	7.62	39.7%	4.7%	46.1%	90.5%	0.60	0.07	0.69	1.37
Goiás	1.14	6.83	7.78	33.1%	4.3%	52.6%	90.0%	0.38	0.05	0.60	1.03
Distrito Federal	0.05	10.15	0.56	23.9%	3.7%	63.6%	91.2%	0.01	0.00	0.03	0.05
N/NE	**3.00**	**2.61**	**7.83**	**13.2%**	**1.9%**	**30.1%**	**45.3%**	**0.40**	**0.06**	**0.90**	**1.36**
C-SOUTH	**12.19**	**6.34**	**77.31**	**33.7%**	**4.5%**	**53.3%**	**91.5%**	**4.11**	**0.55**	**6.50**	**11.15**
BRAZIL	**15.18**	**5.61**	**85.14**	**29.6%**	**4.0%**	**48.8%**	**82.4%**	**4.50**	**0.61**	**7.40**	**12.51**

Source: Céleres®. *Updated in 7 August 2014

Table 7. Biotech Maize Adoption in Brazil, Summer Season

	Planted Area (million hectares)	Yield (t/ha)	Production (million t)	Adoption rate (% of total area)				Biotech Area (million hectares)			
				IR	HT	IR/HT	Total	IR	HT	IR/HT	Total
NORTH	**0.38**	**2.72**	**1.02**	**2.5%**	**1.0%**	**7.6%**	**11.0%**	**0.01**	**0.00**	**0.03**	**0.04**
NORTHEAST	**2.06**	**2.36**	**4.86**	**11.7%**	**2.3%**	**34.5%**	**48.4%**	**0.24**	**0.05**	**0.71**	**1.00**
Maranhão	0.40	2.03	0.82	13.7%	3.4%	55.3%	72.5%	0.06	0.01	0.22	0.29
Piauí	0.39	2.26	0.89	13.7%	3.4%	55.3%	72.5%	0.05	0.01	0.22	0.29
Bahia	0.44	4.54	2.00	26.9%	3.4%	55.3%	85.6%	0.12	0.02	0.24	0.38
SOUTHEAST	**1.60**	**6.96**	**11.10**	**28.2%**	**3.4%**	**58.6%**	**90.2%**	**0.45**	**0.05**	**0.94**	**1.44**
Minas Gerais	1.02	6.96	7.07	28.6%	3.4%	58.3%	90.3%	0.29	0.03	0.59	0.92
São Paulo	0.55	7.15	3.95	27.4%	3.4%	59.3%	90.2%	0.15	0.02	0.33	0.50
SOUTH	**2.13**	**7.03**	**15.00**	**12.7%**	**3.8%**	**73.4%**	**89.9%**	**0.27**	**0.08**	**1.57**	**1.92**
Paraná	0.66	9.46	6.23	12.7%	3.8%	75.1%	91.6%	0.08	0.02	0.50	0.60
Santa Catarina	0.48	7.27	3.46	12.7%	3.8%	73.1%	89.6%	0.06	0.02	0.35	0.43
Rio Grande do Sul	1.00	5.31	5.31	12.7%	3.8%	72.5%	88.9%	0.13	0.04	0.72	0.89
MIDWEST	**0.48**	**8.57**	**4.08**	**14.9%**	**2.8%**	**72.0%**	**89.7%**	**0.07**	**0.01**	**0.34**	**0.43**
Mato Grosso	0.07	7.30	0.54	14.2%	1.7%	69.2%	85.1%	0.01	0.00	0.05	0.06
Mato Grosso do Sul	0.04	8.78	0.34	14.2%	1.7%	70.2%	86.1%	0.01	0.00	0.03	0.03
Goiás	0.33	8.59	2.82	15.1%	3.1%	72.8%	91.0%	0.05	0.01	0.24	0.30
Distrito Federal	0.04	10.82	0.39	15.1%	3.1%	72.8%	91.0%	0.01	0.00	0.03	0.03
N/NE	**2.43**	**2.42**	**5.88**	**10.2%**	**2.1%**	**30.3%**	**42.6%**	**0.25**	**0.05**	**0.74**	**1.04**
C-SOUTH	**4.21**	**7.17**	**30.19**	**18.8%**	**3.5%**	**67.7%**	**90.0%**	**0.79**	**0.15**	**2.85**	**3.79**
BRAZIL	**6.64**	**5.43**	**36.07**	**15.7%**	**3.0%**	**54.0%**	**72.6%**	**1.04**	**0.20**	**3.58**	**4.82**

Source: Céleres®. *Updated in 7 August 2014

Table 8. Biotech Maize Adoption in Brazil, Winter Season

	Planted Area (million hectares)	Yield (t/ha)	Production (million t)	Adoption rate (% of total area)				Biotech Area (million hectares)			
				IR	HT	IR/HT	Total	IR	HT	IR/HT	Total
NORTH	**0.17**	**4.07**	**0.68**	**10.8%**	**1.1%**	**15.0%**	**26.9%**	**0.02**	**0.00**	**0.03**	**0.05**
NORTHEAST	**0.40**	**3.19**	**1.26**	**32.4%**	**1.4%**	**35.5%**	**69.3%**	**0.13**	**0.01**	**0.14**	**0.27**
Maranhão	0.17	4.49	0.74	37.7%	0.0%	37.9%	75.7%	0.06	0.00	0.06	0.12
Piauí	0.03	4.36	0.13	37.7%	0.0%	37.9%	75.7%	0.01	0.00	0.01	0.02
Bahia	0.20	1.94	0.39	27.2%	2.8%	33.2%	63.1%	0.05	0.01	0.07	0.13
SOUTHEAST	**0.53**	**5.26**	**2.78**	**35.7%**	**6.4%**	**44.6%**	**86.7%**	**0.19**	**0.03**	**0.24**	**0.46**
Minas Gerais	0.20	6.72	1.31	35.7%	6.4%	44.6%	86.7%	0.07	0.01	0.09	0.17
São Paulo	0.33	4.40	1.47	35.7%	6.4%	44.6%	86.7%	0.12	0.02	0.15	0.29
SOUTH	**2.00**	**5.88**	**11.75**	**46.2%**	**5.1%**	**44.4%**	**95.6%**	**0.92**	**0.10**	**0.89**	**1.91**
Paraná	2.00	5.88	11.75	46.2%	5.1%	44.4%	95.6%	0.92	0.10	0.89	1.91
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	**5.45**	**5.98**	**32.59**	**40.4%**	**4.8%**	**46.4%**	**91.7%**	**2.20**	**0.26**	**2.53**	**5.00**
Mato Grosso	3.15	6.41	20.19	40.4%	4.8%	47.4%	92.7%	1.27	0.15	1.49	2.92
Mato Grosso do Sul	1.47	4.95	7.28	40.4%	4.8%	45.4%	90.6%	0.59	0.07	0.67	1.33
Goiás	0.81	6.12	4.96	40.4%	4.8%	44.4%	89.6%	0.33	0.04	0.36	0.73
Distrito Federal	0.02	8.89	0.17	40.4%	4.8%	46.4%	91.7%	0.01	0.00	0.01	0.02
N/NE	**0.56**	**3.45**	**1.94**	**25.9%**	**1.3%**	**29.4%**	**56.6%**	**0.15**	**0.01**	**0.17**	**0.32**
C-SOUTH	**7.98**	**5.91**	**47.13**	**41.5%**	**5.0%**	**45.8%**	**92.3%**	**3.31**	**0.40**	**3.65**	**7.37**
BRAZIL	**8.54**	**5.75**	**49.07**	**40.5%**	**4.8%**	**44.7%**	**90.0%**	**3.46**	**0.41**	**3.82**	**7.69**

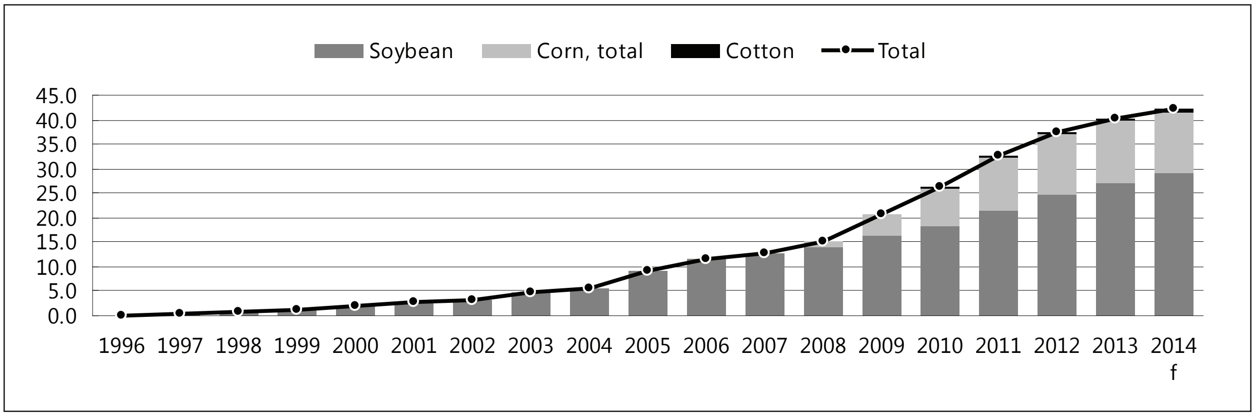
Source: Céleres®. *Updated in 7 August 2014

Table 9. Biotech Cotton Adoption in Brazil

	Planted Area (million hectares)	Yield (t/ha)	Production (million t)	Adoption rate (% of total area)				Biotech Area (million hectares)			
				IR	HT	IR/HT	Total	IR	HT	IR/HT	Total
NORTH	**0.01**	**1.43**	**0.01**	**25.9%**	**15.2%**	**13.5%**	**54.5%**	**0.00**	**0.00**	**0.00**	**0.00**
NORTHEAST	**0.33**	**1.68**	**0.55**	**28.4%**	**19.6%**	**13.4%**	**61.4%**	**0.09**	**0.06**	**0.04**	**0.20**
Maranhão	0.02	1.56	0.03	25.9%	15.2%	13.5%	54.5%	0.01	0.00	0.00	0.01
Piauí	0.01	1.42	0.02	25.9%	15.2%	13.5%	54.5%	0.00	0.00	0.00	0.01
Bahia	0.29	1.72	0.50	28.7%	20.2%	13.5%	62.4%	0.08	0.06	0.04	0.18
SOUTHEAST	**0.03**	**1.57**	**0.04**	**35.8%**	**15.2%**	**14.3%**	**65.2%**	**0.01**	**0.00**	**0.00**	**0.02**
Minas Gerais	0.02	1.57	0.03	35.8%	15.2%	14.3%	65.2%	0.01	0.00	0.00	0.01
São Paulo	0.01	1.55	0.01	35.8%	15.2%	14.3%	65.2%	0.00	0.00	0.00	0.00
SOUTH	**0.00**	**0.86**	**0.00**	**11.1%**	**15.2%**	**10.3%**	**36.5%**	**0.00**	**0.00**	**0.00**	**0.00**
Paraná	0.00	0.86	0.00	11.1%	15.2%	10.3%	36.5%	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	**0.54**	**1.57**	**0.84**	**32.8%**	**26.6%**	**8.2%**	**67.6%**	**0.18**	**0.14**	**0.04**	**0.36**
Mato Grosso	0.45	1.55	0.70	31.7%	25.7%	7.3%	64.8%	0.14	0.12	0.03	0.29
Mato Grosso do Sul	0.04	1.68	0.06	38.3%	38.5%	13.7%	90.5%	0.01	0.01	0.01	0.03
Goiás	0.05	1.67	0.08	38.2%	25.7%	12.1%	76.0%	0.02	0.01	0.01	0.04
Distrito Federal	0.00	1.47	0.00	38.2%	15.2%	12.1%	65.4%	0.00	0.00	0.00	0.00
N/NE	**0.34**	**1.68**	**0.56**	**28.3%**	**19.5%**	**13.4%**	**61.3%**	**0.10**	**0.07**	**0.05**	**0.21**
C-SOUTH	**0.56**	**1.57**	**0.88**	**32.9%**	**26.1%**	**8.4%**	**67.4%**	**0.19**	**0.15**	**0.05**	**0.38**
BRAZIL	**0.90**	**1.61**	**1.45**	**31.2%**	**23.6%**	**10.3%**	**65.1%**	**0.28**	**0.21**	**0.09**	**0.59**

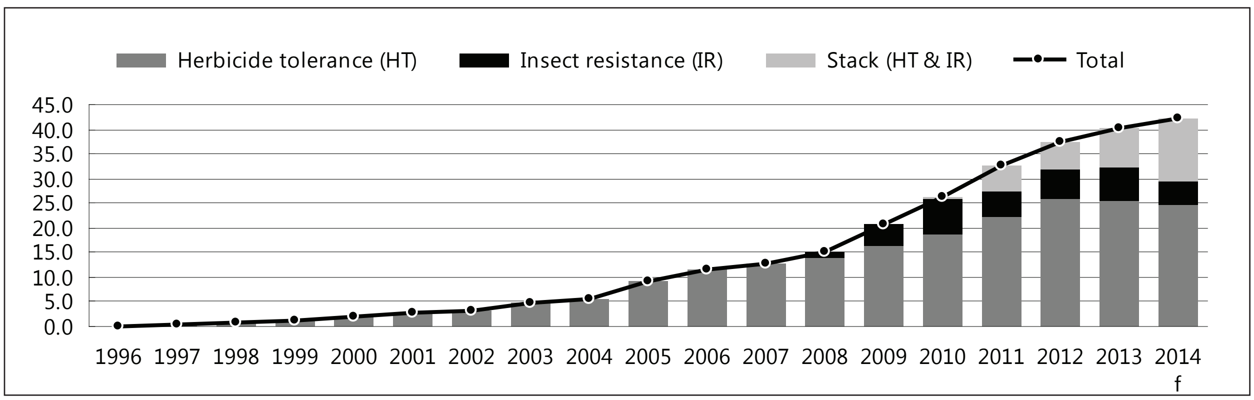
Source: Céleres®. *Updated in 7 August 2014

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



Source: CÉLERES®.

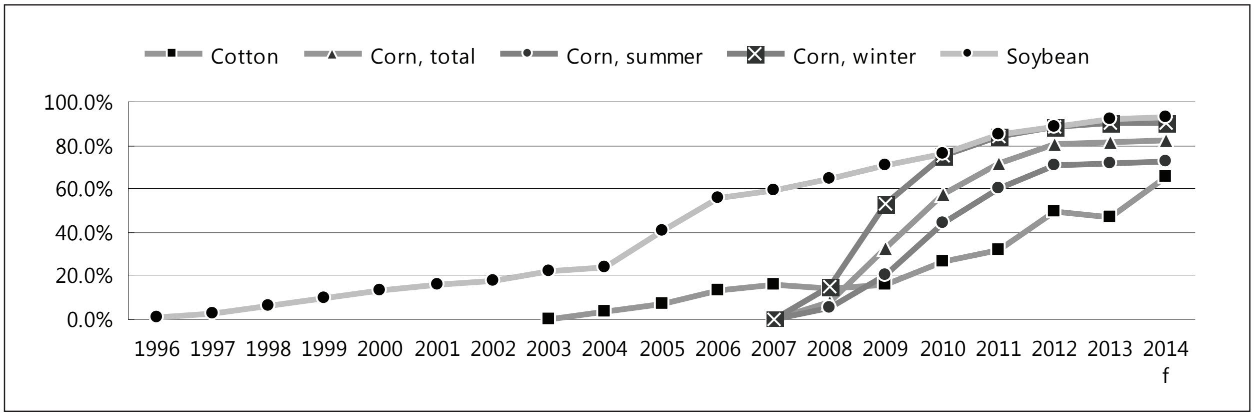
Figure 7. Biotech Crop Adoption in Brazil, by Trait. Values in Million Hectares



Source: CÉLERES®.

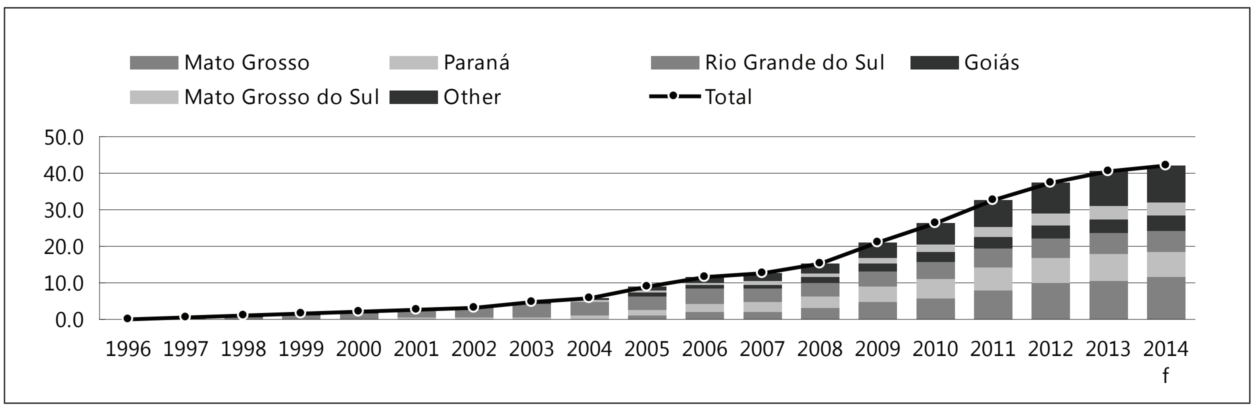
Technology providers were very successful in developing biotech varieties and hybrids well-adapted to the different farming regions in Brazil. A continuous supply of biotech crops was available with adoption progressing quickly from one end of the country to the other (Figure 9). Mato Grosso is still the state with the highest biotech crop hectarage, with 11.4 million hectares (8.1 million hectares of GM soybean, 2.9 million of GM winter maize, 0.3 million hectares of GM cotton and only 0.06 million hectares of GM summer maize). Paraná is the state with the second largest hectarage with 7.1 million hectares (4.6 million hectares of GM soybean, 1.9 million hectares of GM winter maize and 0.6 million of GM summer maize ~ in addition, small hectarages of GM cotton is cultivated in Paraná state on small farms. Rio Grande do Sul was the first state which adopted GM crops in the 1996/97 season and now ranks third place in biotech crop hectarage in Brazil, with 5.9 million hectares (5.0 million hectares of GM soybean and 0.9 million hectares of GM summer maize). The other states include Goiás with 4.3 million hectares, followed by Mato Grosso do Sul, with 3.6 million hectares; and the remaining states of Brazil have less hectarage of biotech crops with a total of approximately 10.0 million hectares.

Figure 8. Evolution of Biotech Adoption Rate in Brazil, by Crop, as % of Total Hectarage



Source: CÉLERES®.

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

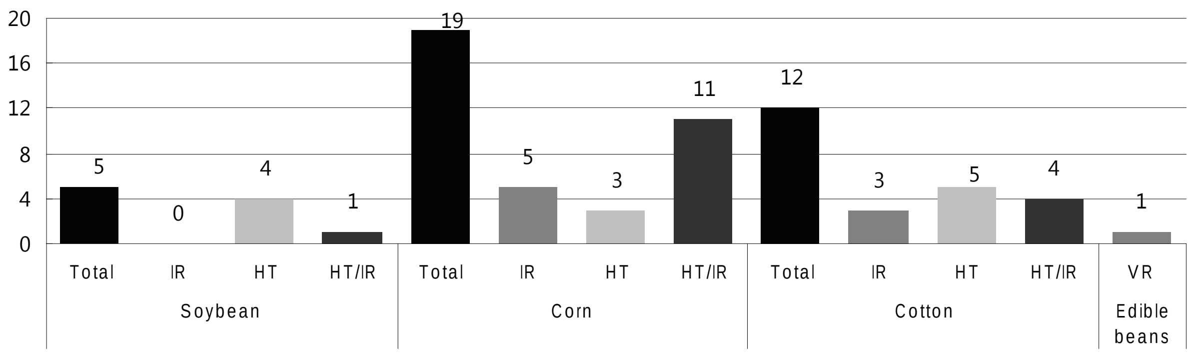


Source: CÉLERES®.

The technical commission responsible for biosafety in Brazil (CTNBio Brazilian National Technical Commission on Biosafety) is regarded as one of the most effective commissions worldwide, with a clear federal biotech regulatory framework and functional approval processes. Compared with past years, when number of approvals per year was very high, approvals for 2013 and 2014 have been low with only one approval in 2013 and none for 2014. To-date Brazil has approved a total of 37 events for planting, which includes five traits for soybeans, 19 for maize, 12 for cotton and one for a home-grown virus resistant bean (Figure 10).

Approvals by the Ministry of Agriculture (MAPA/SNRC), from 2004 to October 2014, include 959 new soybean varieties registered, of which 752 (78%) were genetically modified (with herbicide tolerance and stacked traits) and only 207 (22%) were conventional varieties. In the last three years, a predominance of biotech crops (close to 90%) was clearly evident versus conventional varieties (Figure 11).

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®.

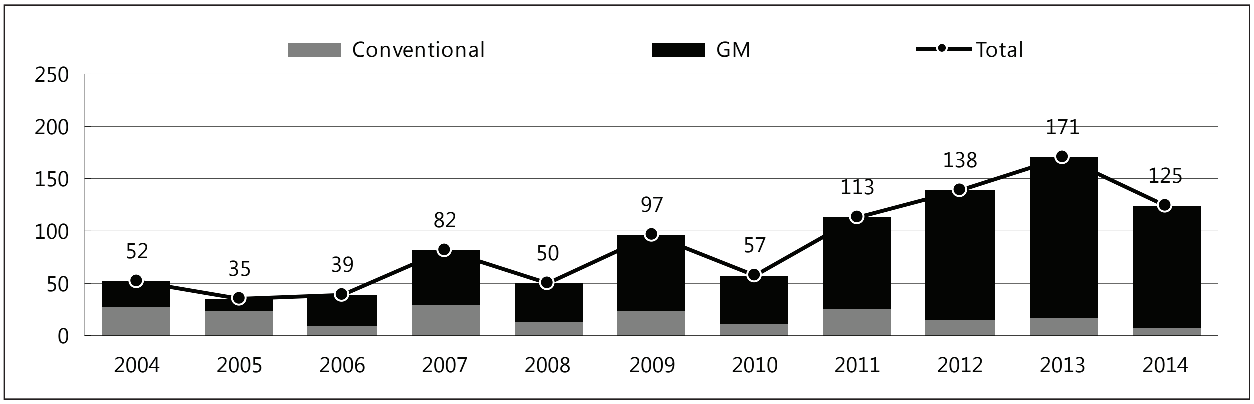
For biotech maize, a significant number of hybrids with biotech traits were registered in the last few years. According to Brazil's Ministry of Agriculture (MAPA/SNRC), from 2004 to 2014, Brazil registered 1,251 maize hybrids, of which, 715 (~57%) were biotech hybrids – this is a significant achievement given that registration of biotech events has only been in effect for only seven years. Since 2009, GM maize hybrids registrations represented the majority of total registered in MAPA/SNRC (71% in 2009, 75.2 in 2010, 67.6% in 2011, 68.9% in 2012, 77.2% in 2013 and 74.6% until October 2014) (Figure 12).

The main reason for high adoption of biotech maize is substantial gains in yield, in all the different maize producing states (Tables 6 to 8). Brazil is an enormous country, with significant differences in crop mega-environments, particularly when considering the differences between summer and winter maize which require quite different technologies and management.

In the winter maize crop season, adoption of biotech crops by farmers is greater and more consistent than is the case for the summer maize. Basically, all of the winter maize is produced by farmers who also grow soybeans in the previous summer, and who are therefore familiar with high-tech biotech crops, particularly biotech soybean. Thus, as expected, biotech maize adoption rate in the winter crop season is higher, reaching a projected 90% in the 2014/15 crop season, whilst summer maize reached a projected 72.6%. This lower level of adoption for summer maize adoption is due to low levels of adoption in North and Northeast of Brazil (11% and 48.4% adoption, respectively). In the North and Northeast, farmers typically use varieties rather than biotech hybrids which are too costly for the predominantly marginal and low tech cropping systems.

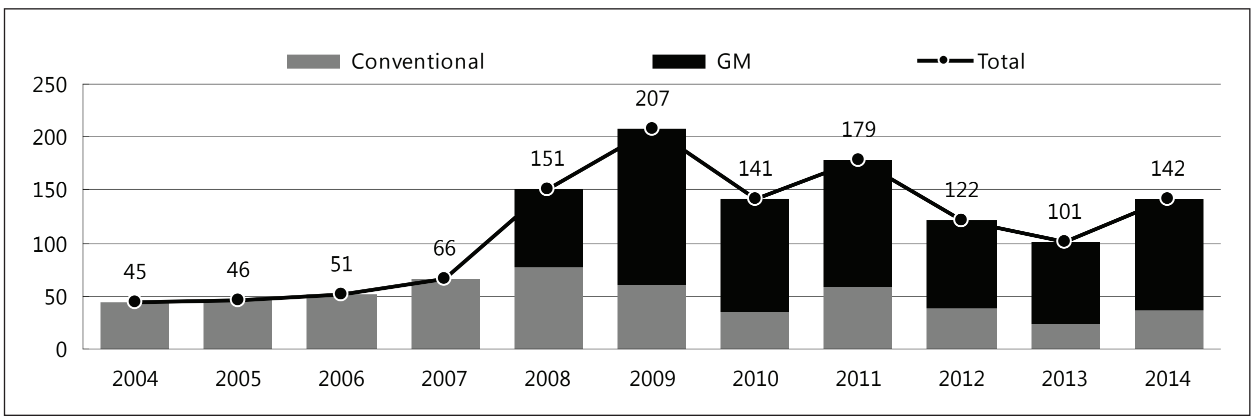
New biotech cotton varieties and technologies have been launched in the last three years, although, the number of registered varieties is still considered small and inadequate by farmers and industry. According to data published by the Ministry of Agriculture (MAPA/SNRC), Brazil registered a total (biotech and conventional) of 97 new cotton varieties since 2004, of which 48 varieties were biotech (49.5% of the total). In the 2012 and 2013 crop season, the proportion of genetically modified registrations was 75% in 2012 and 83.3% in 2013. The latter was a record number of biotech cotton

Figure 11. Register of Soybean Varieties in Brazil



Source: MAPA/SNRC | Elaboration: CÉLERES® | Note: 2014 as of October 7, 2014.

Figure 12. Register of Corn Hybrids in Brazil



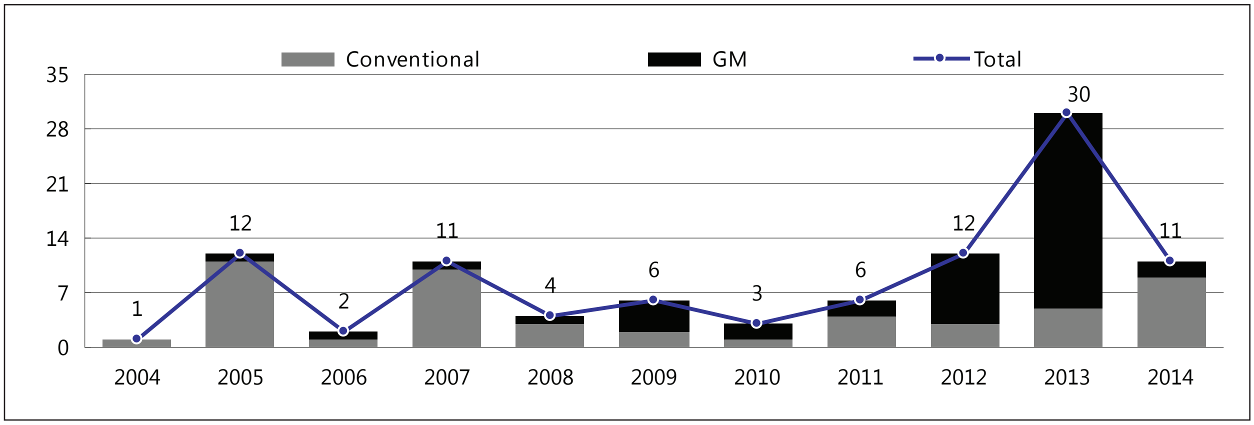
Source: MAPA/SNRC | Elaboration: CÉLERES® | Note: 2014 as of October 7, 2014.

registered varieties (Figure 13) with HT, IR and stack traits. Another important attribute of biotech cotton is that a significant share of the hectares planted to biotech cotton is farmer-saved seed – 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 resulted in disincentives for investors in research and development of biotech cotton, which is clearly reflected by the relatively low number of registered varieties in cotton compared with soybean and maize.

Status of a Soybean Tolerant to Imidazolinone Herbicides

This was the product of a public-private partnership between EMBRAPA and BASF. The product was approved by CTNBio for planting in Brazil in 2010. Commercialization is planned for 2016 pending a final import approval by the EU. The product will provide soybean growers in Brazil with more choices

Figure 13. Register of Cotton Varieties in Brazil



Source: MAPA/SNRC | Elaboration: CÉLERES® | Note: 2014 as of October 7, 2014.

for weed management options. The reader is referred to the section on Future Challenges in this Brief for further details about this product, which will be commercialized as Cultivance™ in 2016.

Virus Resistant Biotech Bean Developed in Brazil

This is a brief overview on the status of the virus resistant bean developed by EMBRAPA in Brazil (Francisco Aragao, 2014. Personal Communication). The gemini virus-resistant bean, (resistant to the bean golden mosaic virus) was generated in 2004. From 2004 to 2010 green house and field evaluations, and biosafety analysis were conducted. In 2010, permission was requested for commercial release of this event in Brazil; it was approved by CTNBio (Brazilian Biosafety Commission) in 2011. Subsequent to obtaining commercial authorization, work was initiated to generate data required by the Brazilian Ministry of Agriculture for registration of all new crop cultivars. The product is expected to be available for commercial seed production by seed companies to supply farmers with commercial seed in early 2016.

A severe outbreak of the bean virus disease was reported in early 2013 in Distrito Federal, when 70% of bean production was lost due to the virus disease caused by golden mosaic virus at a cost of ~US$7 million) to farmers. Cultivation of beans in the affected area was banned by law for 20 days in October which effectively provided the necessary "break" in the infestation of the white fly vectors of the virus. At the national level, it is estimated that the annual loss due to the virus transmitted by the white fly vector is 280,000 Metric tons (15% of national production) and it only takes three white flies per plant to result in a 100% loss in yield. Whereas applying insecticides twice a week for a total of 12 to 14 applications in the season provide effective control of white fly vectors, it does not provide adequate control of the virus disease. It is projected that the new biotech virus resistant bean will: reduce the need for insecticides from 12 to 14 applications to only 3; increase national bean production by up to 30%; and contribute to a more affordable and stable price for beans.

Dr. Mauricio Lopez, President of EMBRAPA, recently commented on the importance of the virus – resistant bean which along with rice is a staple food in Brazil and in Latin America. EMBRAPA invested US$3.5 million over a decade to develop the virus-resistant bean utilizing RNA interference technology to preclude the virus from synthesizing the protein it needs for replication. Dr. Lopez noted that whereas biotech crops are not favored in many countries in Europe they have been the innovative technology that has underpinned success of crops such as RR®soybean in Brazil and now exports in very large tonnages to countries like China. Since RR®soybean was first approved in 2003 it currently has a high adoption rate of more than 85%. The newly approved and first stacked soybean tolerant to herbicide and resistant to insect pests was grown in Brazil in 2013. This is an important step given that insect pests lead to significant losses in tropical countries like Brazil.

Dr. Lopez opined that a big and growing agricultural nation like Brazil cannot afford not to invest in biotechnology because of the multiple advantages it offers – ***"such thinking has guided EMBRAPA since it was founded in 1973"***. EMBRAPA has brought soybean from temperate Asia and grasses from around the world to develop cultivars which can withstand new challenges and stresses that will result from climate change including drought and biotic stresses from pests and diseases that are more severe in a tropical climate like Brazil. With its 400 researchers and an annual budget exceeding US$1 billion, EMBRAPA is well equipped to utilize both conventional and molecular breeding tools to overcome the more challenging crop production constraints that will accompany climate change and when global population will reach 9 billion in 2050 and 10 billion by the turn of the century in 2100. Technology developed by EMBRAPA for Northern areas of Brazil can also be shared with Africa that suffers from similar constraints, and partnerships with African countries are already being established. EMBRAPA is also using precision agriculture and GPS to first measure the needs for inputs of fertilizers and pesticides, and only apply them if needs dictate, thereby optimizing the application of inputs.

However, climate change and the coincidental need to protect the Amazon from deforestation and achieve **sustainability** probably offer the biggest challenge to EMBRAPA and Brazilian farmers. A new 2013 Law requires farmers in the Amazon to preserve 80% of the original habitat and 35% in the Cerrado (savannah) lands of Brazil. EMBRAPA's strategy is embodied within the innovative concept of **sustainable intensification** also favored by many Academies of Science throughout the world. Dr. Lopez opines that ***"there is no need for us to cut down forests for us to reach a new level of productivity"*** (Financial Times of London, 23 October 2013).

Benefits from Biotech Crops in Brazil

Rural producers of cotton, maize and soybean crops first adopted agricultural biotechnology in Brazil 19 years ago. For the seventh consecutive year Céleres® has studied and analyzed the economic benefits resulting from the use of this technology, collected from rural producers and the industries that control the technology. Based on field studies it is estimated that since the introduction of agricultural biotechnology in Brazil in the 1996/97 crop period, the economic benefits to users of this technology ~ in this case rural producers and the controlling industry – have reached US$24.8 billion, which is the result of 17 years of genetically modified crops.

Another annual global study of benefits from biotech crops covering a different period (2003 to 2013) concluded in a provisional data that Brazil gained US$11.8 billion during the ten year period 2003 to 2013 and US$3.4 billion for 2013 alone (Brookes and Barfoot, 2015 Forthcoming). The successful development of the home-grown 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 is also developing other biotech crops, such as biotech sugarcane for sugar and ethanol production with insect resistance. Other biotech crops in the pipeline being developed in Brazil include biotech eucalyptus, rice, wheat, citrus and other crops that are important to the country.

The successful initiative to develop edible beans resistant 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, three in 2012 and just one in 2013, for a total of 27 approvals in 5 years making the country record the fastest approval rate for biotech crops globally, and one of the most rigid and detailed methods for approvals by CTNBio.

ARGENTINA

Total biotech crop hectares in Argentina in 2014 were estimated at 24.3 million hectares, practically the same as 2013, at 24.4 million hectares. Argentina maintained its ranking as the third largest producer of biotech crops in the world in 2014, after the US and Brazil, occupying 13% of global hectarage. In 2014, the 24.3 million hectares comprised 20.8 million hectares of biotech soybean, (similar to 2013) of which 200,000 hectares was Bt/HT soybean, 3.0 million hectares of biotech maize (6% lower than 2013 at 3.2 million hectares) and 0.5 million hectares of biotech cotton (similar to 2013). Farmers substituted maize with soybean because of the higher market prices of soybean, ease and less expensive crop management, and less inputs plus an over-arching general political uncertainty in the country. Positive trade discussions between Argentina and China to export Argentinean biotech maize to China has provided a significant incentive and boost for biotech maize, for the longer term in Argentina. Over the last several years Argentina has achieved a marked improvement in its promotion of biotech crops and has pursued their timely regulation aggressively. Brookes and Barfoot provisionally estimated benefits from biotech crops in Argentina from 1996-2013 that amounted to US$17.5 billion while US$1.9 billion for 2013 alone. 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.

Total biotech crop hectares in Argentina in 2014 were estimated at 24.3 million hectares – similar to 2013 when 24.4 million hectares were planted. The marginal decrease was due to less hectares of maize planted due to unfavorable planting conditions and to a shift from maize to soybean which is an easier crop to grow.

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 37 biotech crop products approved for commercial planting in Argentina and for import as food and feed products are listed in Table 10 including the designation of the event and the year of approval from 1996 to 2014. It is noteworthy that a significant number of 7 new biotech crop events were approved in 2014.

ARGENTINA

Population: 40.8 million

GDP: US$1,842 billion

GDP per Capita: US$10,940

Agriculture as % GDP: 11%

Agricultural GDP: US$163 billion

% employed in agriculture: 1%

Arable Land (AL): 38 million hectares

Ratio of AL/Population*: 3.3

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

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

Total area under biotech crops and (%) increase in 2014:
24.3 Million Hectares (-0.4%)

Farm income gain from biotech, 1996-2013: US$17.5 billion

*Ratio: % global arable land / % global population

The 24.3 million hectares of biotech crops in Argentina is composed of 20.8 million hectares of soybean, 3 million hectares of biotech maize, and 530,000 hectares of biotech cotton. The 20.8 million hectares of biotech soybean is equivalent to 100% adoption.

Of the total maize hectarage in 2014 of 3.75 million hectares, 80% or 3 million hectares were biotech composed of 1.98 million hectares stacked product Bt/HT, 780,000 hectares single Bt product, and 240,000 hectares herbicide tolerant. Thus, the stacked gene Bt/HT maize product occupied about ~66% of the biotech maize and is expected to retain this premier position in the future. Farmers substituted maize for soybean because of the higher prices of soybean, ease and less expensive crop management, less inputs and plus an over-arching general political uncertainty in the country. Positive trade discussions between Argentina and China to export Argentinean biotech maize to China has provided a significant incentive and boost for biotech maize for the longer term in Argentina.

A total of 530,000 hectares was planted to biotech cotton in 2014: an ~100% adoption, composed of 457,000 hectares Bt/HT stacked products, 45,000 hectares herbicide tolerant (HT), and 28,000 hectares

Table 10. Commercial Approvals for Planting, Food and Feed in Argentina, 1996 to 2014

	Crop	Trait	Event	Year
1	Soybean	Herbicide tolerance (HT)	40-3-2	1996
2	Maize	Insect resistance (IR)	176	1998
3	Maize	Herbicide tolerance	T25	1998
4	Cotton	Insect resistance	MON531	1998
5	Maize	Insect resistance	MON810	1998
6	Cotton	Herbicide tolerance	MON 1445	2001
7	Maize	Insect resistance	Bt11	2001
8	Maize	Herbicide tolerance	NK603	2004
9	Maize	HT x IR	TC1507	2005
10	Maize	Herbicide tolerance	GA21	2005
11	Maize	HT x IR	NK603 × MON810	2007
12	Maize	HT x IR	TC 1507 × NK603	2008
13	Cotton	HT x IR	MON1445 × MON531	2009
14	Maize	HT x IR	GA21 × Bt11	2009
15	Maize	Insect resistance	MON89034	2010
16	Maize	HT x IR	MON88017	2010
17	Maize	HT x IR	MON89034 × MON88017	2010
18	Maize	Insect resistance	MIR 162	2011
19	Soybean	Herbicide tolerance	A2704-12	2011
20	Soybean	Herbicide tolerance	A5547-127	2011
21	Maize	HT x IR	Bt11 × GA21 × MIR162	2011
22	Maize	Herbicide tolerance	DP-098140-6	2011
23	Maize	Insect resistance	MIR604	2012
24	Maize	HT x IR	Bt11 × MIR162 × MIR604 × GA21	2012
25	Maize	HT x IR	MON89034 × TC1507 × NK603	2012
26	Maize	HT x IR	MON89034 × NK603	2012
27	Soybean	HT x IR	MON89788 × MON87701	2012
28	Maize	HT x IR	TC1507 × MON 810	2013
29	HT x IR	HT x IR	TC1507 × MON 810 × NK603	2013
30	Soybean	Herbicide tolerance	BPS-CV127-9	2013
31	Maize	HT x IR	Bt11 x MIR 162	2014
32	Maize	HT x IR	Bt11 x MIR 162 x TC1507	2014
33	Maize	HT x IR	Bt11 x MIR 162 x TC1507 x GA21	2014
34	Maize	HT x IR	Bt11 x TC1507	2014
35	Maize	HT x IR	Bt11 x TC1507 x GA21	2014

Table 10. Commercial Approvals for Planting, Food and Feed in Argentina, 1996 to 2014

	Crop	Trait	Event	Year
36	Maize	HT x IR	MIR 162 x TC1507	2014
37	Maize	HT x IR	MIR 162 x TC1507 x GA21	2014

Source: ArgenBio, 2014.

insect resistant (IR). 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.

Over the last several years Argentina has achieved a marked improvement in its promotion of biotech crops and has pursued their timely regulation aggressively. To provide an overview of biotechnology status in Argentina, the following is a summary of the USDA FAS GAIN Report (USDA FAS GAIN, 19 July 2013).

- The revamped regulatory system for agricultural biotechnology launched in 2012 proved to be a successful tool to reduce the approval time for new events. During the first year of the new regulatory framework for agricultural biotechnology, the expected goal of reducing the approval times was accomplished, and proved to be very successful in reducing bureaucracy as well. Several events were approved after its implementation in March 2012.

- Corn growers from Argentina, Brazil, and the United States signed an agreement and created a partnership called MAIZALL, which represents an effective platform for enhancing industry to industry, government to government and public outreach. MAIZALL is intended to provide a mechanism through which producer organizations can collaborate on a global basis to address key issues concerning biotechnology, food security, stewardship, trade and producer image.

- The Argentine industry expressed interest in Brazil's drought resistant sugarcane variety due to its potential to increase the current sugar cane planted area of 350,000 hectares to an estimated planted area of 5 million hectares in ten years. The increase in production would be mainly used for ethanol production. Mission members expressed confidence that the agreement with Brazil would be signed soon.

- The Argentine National Advisory Committee on Agricultural Biotechnology (CONABIA) has been evaluating applications for the Round-up Ready (RR) and the Bt sugarcane varieties. Both varieties have been developed by the Argentine scientists from Obispo Colombres Experimental Research Station, and Santa Rosa Research Institute. It is estimated that the commercial approval for the RR variety may be granted in 2014.

- Argentine researchers have isolated the drought tolerance gene (HB4) from sunflowers, and they have inserted it in varieties of corn, wheat and soybeans with promising results. After three years of field testing in different regions of the country (with different soil conditions and different climates), yields are between 15 and 100% higher than regular. On May 2013, the Argentine firm Bioceres, who has been granted a license for the use and exploitation of this gene, signed joint venture agreements with the French Company Florimond Desprez for wheat variety and US Company Arcadia Biosciences with soybean seeds containing HB4.

- According to contacts within the industry, it is estimated that GE potatoes with virus resistance (Potato Virus Y and Potato Leaf Roll Virus) and herbicide tolerance, currently under CONABIA evaluation, might be commercially approved by the end of 2013. These viruses may cause crop losses of up to 70% in Argentina.

- On June 2013, the Chinese biosafety authority approved several herbicide tolerant soybeans (tolerance to imidazolinone and glufosinate) and corn events including Monsanto's RR2 Bt (approved in Argentina in August 2012). For Argentina, China's approval is important for foreign trade since China is one of the most important markets for Argentine agricultural products. It is expected that the new HT event will increase yields between 8 and 12%, and will reduce glyphosate applications by 70%.

Hence, in 2013 and 2014, Argentina has achieved a marked improvement in development and trade of biotech crops and pursued their timely regulation aggressively. CONABIA has an impressive stable of products for evaluation from both the public and private sector, some of these evaluations may go into fruition soon.

Acceleration of Approval Process for Biotech Crops

Argentina's Agriculture Ministry launched in March 23, 2013 a comprehensive regulatory framework for the assessment and approval of biotech crops. This ends the multi-year regulatory streamlining process and it is expected that the newly implemented framework will boost the process of evaluating the risks and benefits of adopting new biotech crops in Argentina. It took 20 years for Argentina to approve commercial planting of 13 biotech crops, and 15 more were approved in the past three years (Crop Biotech Update, 10 April 2013).

Argentine Scientists Develop Virus Resistant GM Potato

Argentine scientists have developed potato plants resistant to Potato Virus Y (PVY), a disease that reduces crop yields from 20 to 80 percent. The team is led by Fernando Bravo Almonacid from the National Research Council of Argentina, CONICET at the Institute for Research on Genetic Engineering and Molecular Biology (INGEBI, CONICET-UBA). For six years, researchers have tested 2,000 plants from two different lines in the provinces of Córdoba, Mendoza and Buenos Aires. Results showed that the genetically modified (GM) plants were not infected, while the infection rate was 60 to 80 percent in non-GM plants. The research was conducted under the supervision of Argentina's Ministry of Agriculture, Livestock and Fisheries (Crop Biotech Update, 7 August 2013).

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 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 11).
- 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).
- 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

Table 11. 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.

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 provisional data on the benefits from biotech crops, Brookes and Barfoot (2015, Forthcoming) estimates that Argentina has enhanced farm income from biotech crops by US$17.5 billion in the first eighteen years of commercialization of biotech crops 1996 to 2013, and the benefits for 2013 alone were estimated at US$1.9 billion.

Farmer Experience

<u>Martin Arechavaleta is a soybean grower and a third generation farmer in Victoria, Province of Entre Rios, Argentina</u>. 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).

<u>Mario Alberto Sanchez</u>, 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).

In a study by Massarani et al. (2013) on perception of small farmers in Argentina about genetically modified crops, results showed that local small farmers are satisfied with the new technology but also have fears concerning the environment and social impacts. Majority of the farmers stated that GM plants are more profitable and require less work. The generally favorable attitude goes hand-in-hand with other concerns, such as human consumption of genetically modified food or the use of GM technology for research purposes in medicine which are acceptable provided control procedures and access to clear information are improved. In addition, participants agreed that they should be heard in the decision-making process for agricultural questions, but also recognized the difficulties in achieving this objective.

INDIA

In 2014, the adoption of Bt cotton in India increased by 600,000 hectares to a record 11.6 million hectares, equivalent to a high adoption rate of 95% of 12.25 million hectares total cotton area. In 2014, India planted the largest ever area of cotton – 105,000 ha more than the previous record cotton area of 12.1 million ha in 2011. Thus, in 2014, India achieved a near– optimal adoption rate of 95% at the national level, and this was distributed evenly among the ten cotton growing States. The number of Bt cotton farmers increased to 7.7 million in 2014 from 7.3 million in 2013.

In the thirteen year period, 2002 to 2014, India tripled cotton production from 13 million bales to 39 million bales in 2013, with a projected 40 million bales in 2014. World cotton production was estimated at 151 million bales in 2014, and impressively, India contributed one quarter of this global total. As a result of this phenomenal increase in cotton production in the recent years, India surpassed USA in 2006 to become the second largest cotton producing country and is projected to surpass China in 2014 to become the number one cotton producer in the world. Thirteen years ago, China produced twice as much as India's cotton production of 13 million bales in 2002. The phenomenal increase in cotton production in India in the period 2002 to 2014 is due to the structural transformations in the cotton value chain driven by multiple factors including: the high and broad scale adoption of Bt cotton technology; hybridization of the cotton crop, supply of good quality seeds by the private sector and last but not least the untiring efforts of millions of small resource-poor cotton farmers. The resurgence of cotton, the white gold of rural India can help resurrect the spirit of the Gandhian 'spinning wheel' and the glory of the cotton and textile sectors in the country.

In 2014, GEAC's Standing Committee on Approved Bt Cotton Events, released an additional 70 Bt cotton hybrids for a total of around 1167 Bt cotton hybrids: the crosses made during the period 2002 to 2014 are predominantly *G. hirsutum* x *G. hirsutum* with a few consisting of *G. hirsutum* x *G. barbadense*. Importantly, India has already achieved a near phasing-out of the Bollgard™1 event, which has now been almost completely replaced with the dual gene Bollgard™ II (BG-II) cotton event. In 2014, India was gearing up to consider the approval of the country's first stacked trait – the insect resistant and herbicide tolerant cotton, Bollgard II Roundup Ready cotton (BG-II RRF™). The

planting of a high density cotton and developing a CLCV tolerant Bt cotton hybrids are two very important ongoing initiatives that will help shape the future of cotton cultivation in India.

In 2014, India has made significant strides on the regulatory front which was stalled after the moratorium on Bt brinjal on 9th Feb 2010. Bt brinjal is now being planted commercially in neighboring Bangladesh while Indian farmers still have to rely heavily on a cocktail of pesticide sprays to control the menacing fruit and shoot borer, the major pest of brinjal in India. In addition to granting approval for conducting field trials of GM crops, including mustard, chickpea, brinjal, rice and cotton, GEAC also approved four biotech events of soybean (for import and use as feed), namely MON87701 x MON89788, A5547-127, A2704-12 and BPS-CV-127-9. This approval is a major step to relieve the pressure on the demand and supply of edible oil, which is a key ingredient for Indian cooking. India imports large quantities of palm oil, soybean oil and canola oil from major GM producing countries of North and Latin America. India also blends a sizable quantity of domestic cotton oil, (approximately 1.5 million tons per annum) to boost the supply of edible oil in the country.

INDIA

Population: 1,241.5 million

GDP: US$1,873 billion

GDP per Capita: US$1,510

Agriculture as % GDP: 18%

Agricultural GDP: US$337.1 billion

% employed in agriculture: 51%

Arable Land (AL): 174.2 million hectares

Ratio of AL/Population*: .65

Major crops:

- Sugarcane
- Vegetables, fresh
- Rice, paddy
- Potato
- Wheat
- Cotton

Commercialized Biotech Crop: Bt Cotton

Total area under biotech crops and (%) increase in 2014:
11.6 Million Hectares (+5%)

Farm income gain from biotech, 2002-2013: US$16.7 billion

*Ratio: % global arable land / % global population

In 2014, the Government of India filed an affidavit in the Supreme Court of India seeking the continuation of scientific experiments and field trials of GM crops - this was in response to the two contradictory reports submitted separately by members of the Technical Expert Committee (TEC), appointed by the Supreme Court of India. The Government's affidavit submitted jointly by MOEF, MOA and MOST assumes significance given the suspensions and delays of biotech projects in agriculture caused by the Public Interest Litigation (PIL) on GM crops filed by an NGO in 2005. The court's verdict on the ongoing PIL on GM crops is expected to be delivered anytime in 2014/2015 to resolve the impasse on the current regulatory system of GM crops in India. Brookes and Barfoot provisionally estimated that India had enhanced farm income from Bt cotton by US$16.7 billion in the twelve year period 2002 to 2013 and US$2.1 billion in 2013 alone.

India Becomes the Number One Cotton Producing Country in the world

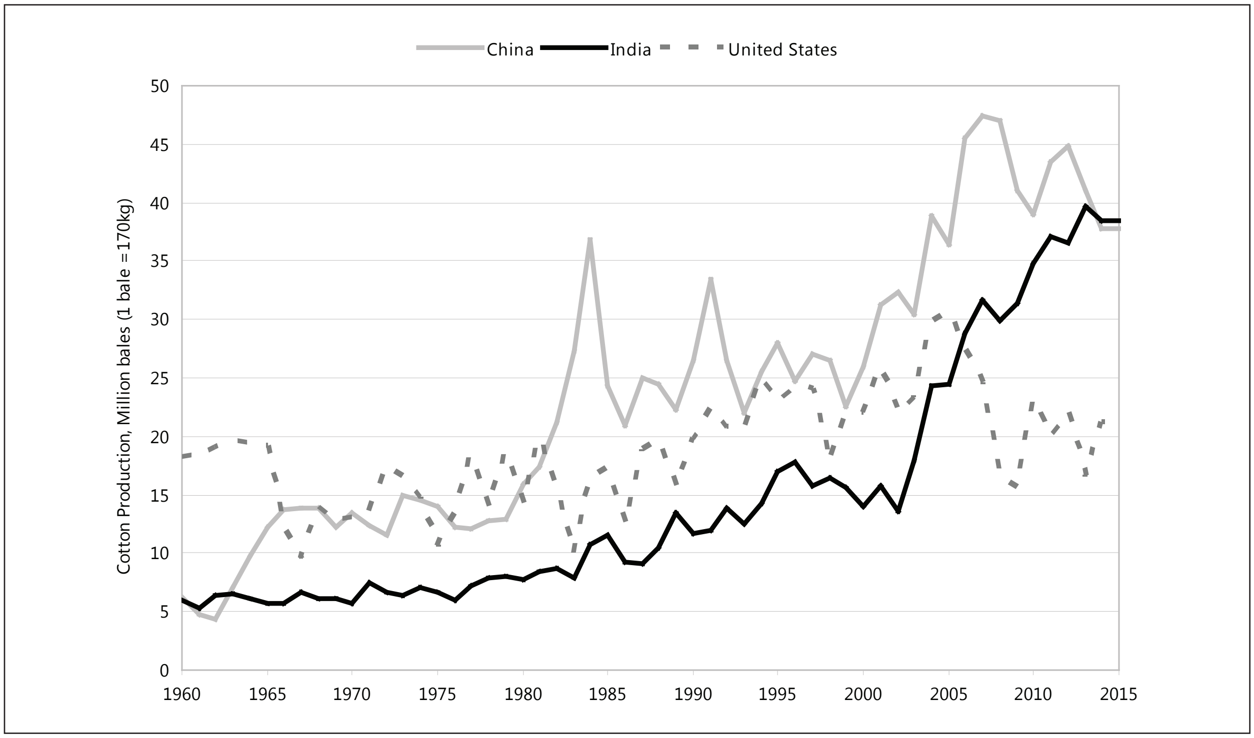
In 2014, India achieved a historic milestone by producing more cotton than China and becomes the number one cotton producing country in the World. For the first time in the history of agriculture, India dethroned China to earn the crown of the white gold – as cotton is known among smallholder farmers in the rural parts of India and China (USDA, 2014; Reuters, 2014). In 2006, India displaced USA to third position by harvesting 28 million bales – a million more than USA to become the second largest cotton producing country (USDA, 2007). Over the subsequent eight years, 2007-2015, India sustained the growth of cotton primarily due to the introduction and rapid adoption of dual gene Bt cotton technology coupled with a large scale hybridization of cotton area, supply of good quality seeds by private sector and untiring efforts by approximately 8 million cotton farmers in the country.

However, in recent years, China massively supported the purchase of cotton domestically and substantially increased cotton imports resulting in the stockpiling of cotton estimated to be over 45 million bales above average equivalent to one third of the world's cotton production in 2014 (USDA, 2014). To overcome the stockpiling, China planned to cut cotton planting and production that would spur the utilization of cotton stocks. As a result, farmers in China planted less cotton area and reduced production amid uncertainty over the Chinese cotton support program at domestic level (Reuters, 2014). The OECD/FAO Global Agricultural Outlook 2014 report projected that China's cotton production would decline by 17% over the next few years. On the contrary, India substantially increased area under cotton, estimated to produce a record 40 million bales of cotton in 2014, compared to 39 million bales in 2013 and 35 million bales in 2012. As a result of the phenomenal increase in cotton production, India surpassed China to occupy the top cotton producing country in the world in 2014 (OCED/FAO, 2014; USDA, 2014). Figure 14 shows the trend in cotton production over a 40 year period, 1960 to 2014 of top three cotton producing countries including China, India and USA. The trend lines distinctively indicate a steep increase in cotton production in USA beginning 1996, China in 1997 and India in 2002 corresponding with the introduction of the insect resistant Bt cotton in these countries.

Notably, over the thirteen year period, India doubled its market share of global cotton production from 12% in 2002 to 25% in 2014, representing a quarter of total global cotton production. India replaced China as the largest cotton producer in the world with India's cotton market share marginally higher than China's 25% in 2014. The distribution of market share of cotton by top five cotton producing countries in 2002 and 2014 is shown in Figure 15.

The commercial approval of Bt cotton in 2002 was a breakthrough step to revive the ailing cotton sector in the country. The cotton industry then was characterized by 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 2014, 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 before reaching the highest national cotton yield of 570 kg per hectare in 2013-14. Cotton production increased from 13.6 million bales in 2002-03 to 39 million bales in 2013-14, which was a record cotton crop for India. Notably, the States of Punjab, Haryana and Gujarat have crossed the average yield of 750 kg lint per hectare at the State level, which is higher than the average world cotton yield. Similarly, other States that predominantly grow cotton in rainfed conditions have also shown the

Figure 14. Top Three Cotton Producing Countries in the World, 1960 to 2014

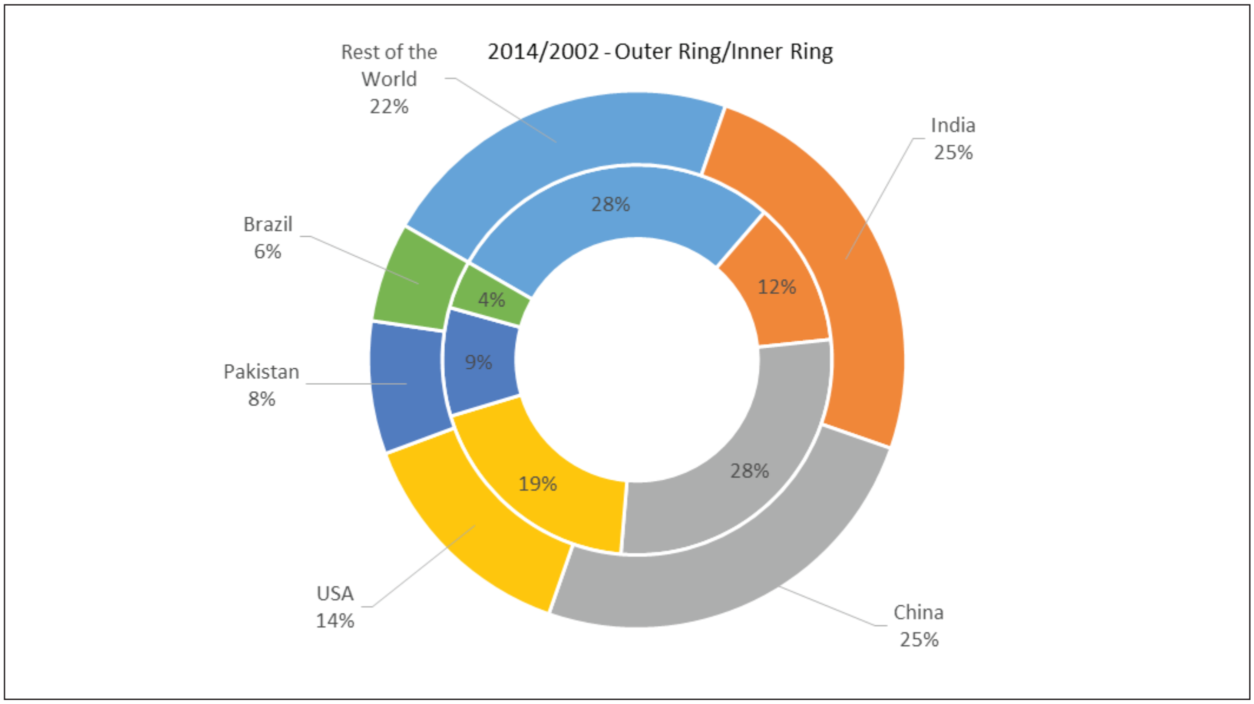


Source: USDA, 2014, Analyzed by ISAAA, 2014

remarkable hike in cotton yield in 2014 up to 360 kg lint per hectare in 2013 in Maharashtra and 570 kg lint per hectare in Andhra Pradesh, to name a few (CAB, 2014). Figure 16 shows the upward trend in cotton production which remained below 15 million bales until the introduction of Bt technology in 2002-03.

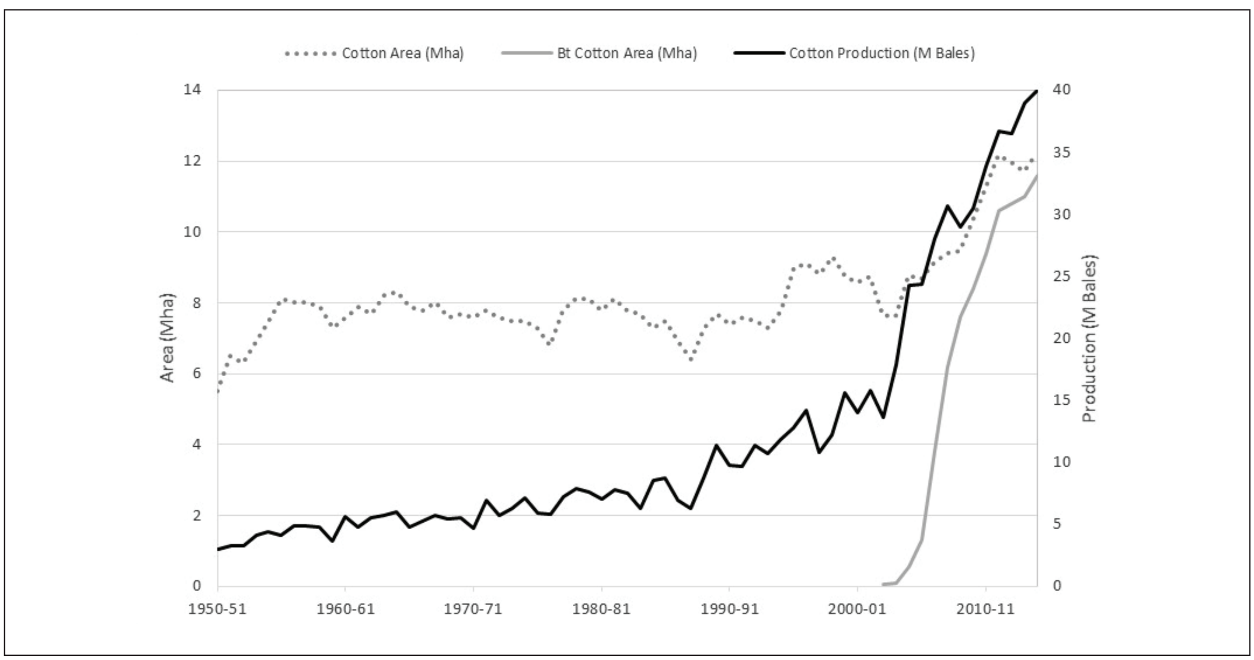
The phenomenal rise in cotton production is attributed to the wide scale adoption of Bt cotton, single gene Bt cotton from 2002 to 2006 and dual gene Bt cotton from 2006 onward, by smallholder cotton farmers across the ten cotton growing States. In 2014, 7.7 million cotton farmers adopted Bt cotton representing 95% of estimated 12.25 million cotton farmers in India. In recent years, farmers increased the density of cotton planting particularly in irrigated and semi-irrigated conditions that led to substantial increase in cotton productivity per hectare across the board. Table 12 shows the adoption and distribution of Bt cotton in the major cotton growing states from 2002 to 2014. The major states growing Bt cotton in 2014, listed in order of hectarage, were Maharashtra (3.9 million hectares) representing 32% of all Bt cotton in India, followed by Gujarat (2.5 million hectares or 21%), Andhra Pradesh and Telangana (2.3 million hectares or 18.6%), Northern Zone (1.4 million hectares or 11.6%), Madhya Pradesh (560 thousand hectares), and the balance of 835 thousand hectares in Karnataka, Tamil Nadu and other cotton growing States including Odisha. 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

Figure 15. Distribution of World Cotton Market Share by Top Five Producing Countries, 2002 and 2014



Source: USDA, 2014

Figure 16. The Adoption and Impact on Bt Cotton on the Cotton Production in India, 1950 to 2014



Source: CAB, 2014; Blaise et al., 2014; Analyzed by ISAAA, 2014

Table 12. Twelve Years of Adoption of Bt Cotton in India, by Major States*, 2002 to 2014 (Thousand Hectares)

State	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Maharashtra	25	30	200	607	1,840	2,800	3,130	3,396	3,710	3,960	3,995	3,860	3,950
Andhra Pradesh	8	10	75	280	830	1,090	1,320	1,049	1,650	1,820	1,935	2,100	2,275
Gujarat	10	36	122	150	470	908	1,360	1,682	1,780	1,930	2,015	2,130	2,525
Madhya Pradesh	2	13	80	146	310	500	620	621	610	640	605	620	560
Northern Region*	-	-	-	60	215	682	840	1,243	1,162	1,340	1,390	1,365	1,425
Karnataka	3	4	18	30	85	145	240	273	370	570	520	580	610
Tamil Nadu	2	7	5	27	45	70	90	109	110	220	220	194	110
Others	-	-	-	-	5	5	5	8	8	120	120	146	115
Total	**50**	**100**	**500**	**1,300**	**3,800**	**6,200**	**7,605**	**8,381**	**9,400**	**10,600**	**10,800**	**10,995**	**11,570**

Source: Analysed and Compiled by ISAAA, 2014.

crop in the past. Evidently, the country achieved a near phasing out of single gene Bollgard-1 cotton hybrids, which has been almost replaced with dual gene Bollgard-II (BG-II™) cotton hybrids introduced in 2006. The double gene Bt cotton hybrids provide additional protection to *Spodoptera* (a leaf eating tobacco caterpillar) while protecting cotton crop from 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.

In addition, the Genetic Engineering Appraisal Committee (GEAC) deregulated six Bt cotton events consisting of single and double gene(s) belonging to public and private sector institutions between 2002 and 2014. These events included MON531 harboring *cry1Ac* gene, followed by first two-gene event MON15985 (*cry1Ac* and *cry2Ab2*), Event-1 (*cry1Ac*), GFM event (fused genes *cry1Ab* and *cry1Ac*), BNLA-601 event (*cry1Ac*) and MLS-921 (synthetic *cry1C*). Event BNLA-601 with *cry1Ac* gene was introgressed to an open pollinated variety and a hybrid. This was the first event developed by public sector institutes in India but was discontinued in 2010 for scientific validation and evaluation. Over the last thirteen years, India has greatly diversified deployment of approved events into different cotton genotypes, which are well-adapted to India's agro-ecological zones to ensure equitable distribution to small and resource-poor cotton farmers. The significant increase in area under hybrid cotton cultivation is credited to the introduction of Bt technology which spurred the hybridization of cotton from three Bt cotton hybrids in 2002-03 to 1097 Bt cotton hybrids in 2013 and at the same time, the area of cotton hybrids increased significantly to 95% in 2013 from 45% in 2001.

In 2014, GEAC's Standing Committee on the Approved Bt Cotton Events released additional 70 Bt cotton hybrids for a total of around 1167 Bt cotton hybrids to cotton farmers across 10 cotton growing States. Majority of Bt cotton area was occupied by hybrids *G. hirsutum* x *G. hirsutum* and a few consisting of *G. hirsutum* x *G. barbadense* whereas remaining non-Bt cotton area was occupied either by non-Bt cotton hybrids refuge or desi cotton varieties of *G. arboreum* and *G. herbaceum*. Table 13 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, 44 and 46 (James, 2011, 2012 and 2013) provides the details of the approval of different Bt cotton events and hybrids, and adoption and spread of single and double gene Bt cotton hybrid from 2002 onwards.

In addition to boosting cotton production in the last thirteen years, Bt cotton has made a substantial contribution to stem the cost of production by drastically reducing applications of insecticide sprays to control key cotton pests such as American bollworm, pink bollworm, spotted bollworm and *Spodoptera*. On average, Bt cotton helped farmers to reduce insecticide sprays from more than two dozen (24) sprays to 2-3 sprays in a season. Traditionally, cotton consumed more insecticides than any other crop equivalent to 46% of the total insecticide market for all crops in India (Kranthi, 2012). Over the years, the market share for cotton insecticides as a percentage of total insecticides declined steeply from 46% in 2001, to 26% in 2006 and to 20% in 2011.

Notably, there has been a very steep decline in insecticide usages particularly on *Helicoverpa armigera* from 71% in 2001 to 3% in 2011. 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 a time when total pesticides market in the country increased significantly during the same period (CIBRC, 2012).

Table 13. Deployment of Approved Bt Cotton Events/Hybrids/Variety by Region in India in 2014

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: Analyzed and Compiled by ISAAA, 2014.

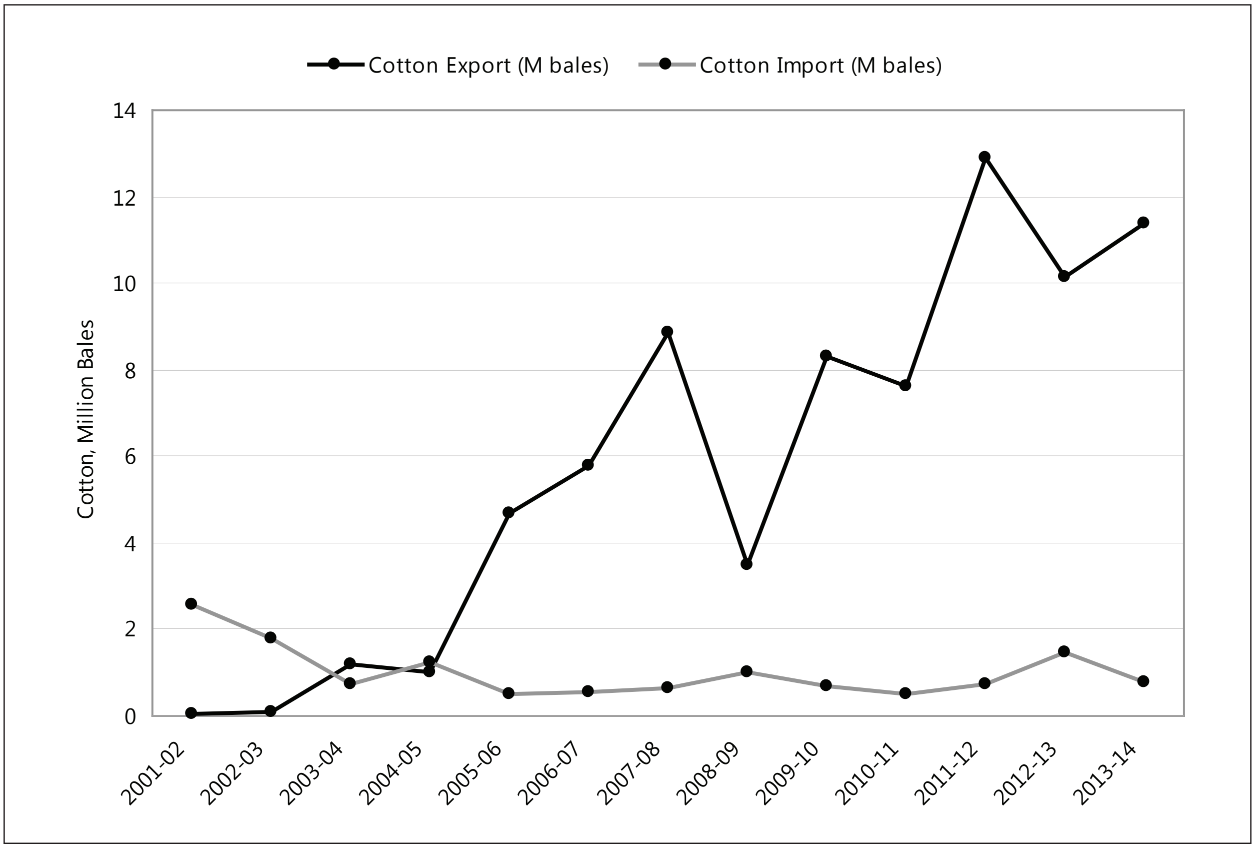
This saving in insecticides on cotton between 2004 and 2014 coincided with the large scale adoption of Bt cotton from half a million hectares in 2004 to 11.6 million hectares in 2014-15, equivalent to 95% of the total cotton crop in 2014-15.

Likewise, Bt cotton ensured the sustained supply of raw cotton to meet the growing demand of the domestic textile industry, which earned US$39 billion from export of textile in 2013-14 (PIB, 2014). In the past, the Indian textile industry was dependent on the imported cotton. Bt cotton transformed India 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 11.4 million bales in 2013-14 (CAB, 2014) while cotton import gradually declined to a million bales, primarily the extra-long staple (ELS) cotton. As per the Cotton Corporation of India (CCI), the quality of cotton has improved to the international standard with more than 80% of cotton now constitutes long staple cotton (27.5 to 33mm). India is the world's largest cotton exporting country with recorded cotton export ranging between 8 to 12 million bales over last few years (Figure 17) (PIB, 2013). In order to arrest the policy uncertainty of cotton trade, the Ministry of Textile of the Government of India has drafted the Cotton Trade (Development and Regulation) Bill 2012 which seeks to safeguard the interests of the textile industry, trade and consumers. The bill aims to set up a new system of realistic assessment of the distribution and consumption of raw cotton (Ministry of Textile, 2013; CAB, 2013).

GM Crops and Indian Edible Oil Sector

Edible oil is a vital ingredient of the deep-fried cooking and the Indian diet. Annually, India consumes approximately 18 million tons of edible oil of which 40% is produced domestically and remaining 60% is imported to meet domestic consumption. Crops like soybean, mustard, cotton, groundnut, sunflower

Figure 17. Export and Import of Cotton in India, 2001 to 2014



Source: CAB, 2014, Analyzed by ISAAA, 2014

and other minor crops are the major sources of domestic supply whereas the majority of imported edible oil is sourced primarily from palm and soybean (MOA, 2014). Over the years, India's reliance on imported edible oils has soared. In 2014, India imported the largest quantity of edible oil of 11.4 million tons which was around 65% of the total domestic consumption (Reuters, 2014a). The import of edible oil costs approximately Rupees 60,000 crore or around US$10 billion in 2014 alone, making it the third largest import bill after petroleum products and gold. Almost all soybean oil imported from North America and Latin America are derived from genetically modified soybean. In 2013, the adoption of genetically modified soybean was over 93%, 92% and 100% of total soybean area in USA, Brazil and Argentina, respectively. In summary, India imports more than 1 million tons of GM soybean oil annually, which is a significant part of edible oil import. GEAC approved the first GM soybean event, Roundup Ready to Yield, MON89788 (RR2Y™) for import of soybean oil for food in 2010. Subsequently, in 2014, four additional events of GM soybean were approved for food and feed import. These events are approved and form a substantial part of imported GM soybean oil in the country, as listed in order of approval by GEAC in Table 14.

Table 14. Import Approval of Soybean Events for Food and Feed in India, 2010 to 2014

No.	Crop	Event	Developer	Purpose	Year of approval by GEAC
1	Soybean	MON89788 (RR2Y)	Monsanto India	Import for Food & Feed	12 May 2010
2	Soybean	MON87701 x MON89788 (Genuity Insect Protected Roundup Ready 2 Yield – BtRR2Y)	Monsanto India	Import for Food & Feed	18 July 2014
3	Soybean	A5547-127 (Liberty Link)	Bayer Biosciences	Import for Food & Feed	18 July 2014
4	Soybean	A2704-12 (Liberty Link)	Bayer Biosciences	Import for Food & Feed	18 July 2014
5	Soybean	BPS-CV-127-9 (CV127)	BASF India	Import for Food & Feed	18 July 2014

Source: GEAC, 2014; Compiled by ISAAA, 2014

In addition to GM soybean oil, India annually consumed approximately 1.5 million tons of cotton oil which was produced domestically from the genetically modified Bt cotton that occupied 95% of total cotton planted in 2014 alone. The production of cotton seed, and its by-products as oil and meal, has increased manifold from 0.46 million tons in 2002-03 to 1.5 million tons in 2014-15 – a three-fold increase in cotton oil production in the last thirteen years. Notably, Bt cotton meal (de-oiled cake) contributes more than one third of the country's total demand for animal feed, whereas cotton oil contributes around 20% of total edible oil production for human consumption in the country. Due to the high nutritional content of cotton oil, Bt cotton oil is marketed after blending it with different edible oils. So far, India consumes a significant amount of Bt cotton oil (20% of total domestic production) and Bt cotton cake contributes one third of the total animal feed from 2002 to 2014, and thus contributed significantly to food (as edible oil), feed (as de-oiled cake) and fibre security. Table 15 shows the trend of Bt cotton oil production in India, from 2002 to 2014.

In summary, India becomes a major consumer of genetically modified food, as it consumes edible oil produced domestically from Bt cotton and from imported soybean oil derived from GM soybean. A massive amount of edible oil derived from Bt cotton and GM soybean, roughly 2.5 million tons (1.5 million tons Bt cotton oil and 1 million ton GM soybean oil) is consumed annually in India without any reported health issue. Like Bt cotton, India should therefore, consider genetically modified soybean and mustard that can help the country to substantially increase production of edible oil to decrease its reliance on imported edible oil.

Table 15. Contribution of Cotton Oil to the Edible Oil Sector in India, 2002-03 and 2013-14

Item	2002-03	2013-14
Cotton production (million bales)	13.6	39.1
Cottonseed production @ 310kg/bale (million tons)	4.21	12.1
Retained for sowing & direct consumption (m tons)*	0.50	0.1
Marketable Surplus (million tons)	3.71	12
Production of washed cottonseed oil (12.5%) (m tons)	0.46	1.5

*Very few farmers retain cotton seed for sowing over the last thirteen years as cotton hybrid seed planting increased to 95% of cotton area. Cotton hybrid seeds production is undertaken separately by specialized cottonseed growers and marketed by private seed sector in the country.

Source: COOIT, 2010; AICOSCA, 2010; CAB, 2014; Compiled by ISAAA, 2014

Pending Commercial Approval and Resumption of Field Trials of GM crops in India

In 2014, GEAC resumed meeting regularly and approved the field trials of GM mustard, Bt chickpea, NUE rice and Bt brinjal in meetings held in August and Sept 2014. GEAC has considered the application of Bollgard-II Roundup Ready cotton, the country's first stacked trait event MON15985 X MON88913, insect resistant and herbicide tolerant cotton in 2014/early 2015. GEAC was gearing up to approve the commercial release of BG-IIRRF cotton event, seventh Bt cotton event since the first commercial approval of Bollgard BG-I event MON531 in 2002. Notably, in 2014, India planted 11.6 million hectares of Bt cotton equivalent to 95% of the total cotton area of 12.25 million hectares.

Table 16 shows the status of pending commercial approval of the first stacked Bt cotton event, Bollgard®II (BG®II) Roundup Ready Flex (BGIIRRF®) and resumption of field trials of other GM crops in Rabi season in 2014. The BGIIRRF cotton event is being developed by Mahyco and sourced from Monsanto, and for the first time features stacking of two events in India including insect resistance and herbicide tolerance in cotton. Bollgard®II (BG®II) Roundup Ready Flex (BG®II RRF) expresses three genes; *cry1Ac* and *cry2Ab* to confer insect resistance and CP4EPSPS genes to impart herbicide tolerance. It completed all the regulatory requirements including different stages of field trials in India and a dossier was prepared and submitted for the commercial release in 2014. BGIIRRF cotton event will be a milestone achievement as it is India's first herbicide tolerant trait and is likely to be approved for commercial release in early 2015.

The second most significant event for the new Government of India was to revisit the decision imposing moratorium on Bt brinjal on 9 Feb 2010 (MOEF, 2010). As a consequence of the moratorium on Bt brinjal, India's regulatory system came to a deadlock resulting in irregular meeting of the regulatory committees and halting of field trials of GM crops in the country in the last five years. Contrary to the MOEF's decision, the Genetic Engineering Appraisal Committee (GEAC), the country's biotech regulator, in its 97th meeting held on 14th Oct 2009 recommended the commercial release of Bt Brinjal Event EE-1 developed indigenously by M/s Maharashtra Hybrid Seeds Company Ltd. (Mahyco) in collaboration with the University of Agricultural Sciences (UAS), Dharwad, the Tamil Nadu Agricultural University

Table 16. Status of Biotech/GM Crops Pending Approval for Field Trials and Commercial Release in India, 2014-2015

Crop	Organization	Gene/Trait	Pending Status
Cotton	Mahyco/Monsanto	*cry1Ac* and *cry2Ab*/IR&HT	Pending commercial approval
Brinjal	Mahyco	*Cry1Ac*	Under Moratorium
Mustard	Delhi University, New Delhi	*bar, barnase, barstar*/AP	Final stage
Brinjal	Bejo Sheetal/IARI	*cry1Aabc*/IR	BRL-II stage
Chickpea	Sungro Seeds	*Bt*	BRL-I stage
Rice	Mahyco	*NUE*	BRL-1 stage

Source: Analyzed and compiled by ISAAA, 2014

(TNAU), Coimbatore and the Indian Institute of Vegetable Research (IIVR), Varanasi (GEAC, 2009a; MoEF, 2009). The recommendation came seven years after the approval of Bt cotton, the country's first biotech crop which was already planted by 5.6 million farmers on 81% of total cotton area that time in 2009. Bt brinjal, which is resistant to the dreaded fruit and shoot borer (FSB), has been under research and development and a stringent regulatory approval process in India since 2000. However, on 9th Feb 2010, the Ministry of Environment and Forest (MOEF) decided to temporarily halt the commercial release of Bt brinjal until such time independent scientific studies are established, to the satisfaction of both the public and professionals, the safety of the product from the point of view of its long-term impact on human health and environment, including the rich genetic wealth existing in brinjal in India (MOEF, 2010).

In response to the moratorium on Bt brinjal in Feb 2010, efforts were made to address the concerns and raise awareness about the potential benefits of Bt brinjal to farmers and consumers in the country. Following developments on Bt brinjal should compel the Government of India to revisit the moratorium on Bt brinjal in the country;

- Six top science academies of India reviewed and ultimately endorsed the safety of Bt brinjal and recommended limited release of Bt brinjal in the "Inter-Academy Report on GM Crops" released in September 2010 and further updated in December 2010. Vindicating the doubt raised by opponents of the technology, the Academy Report states that "the overwhelming view is that the available evidence has shown, adequately and beyond reasonable doubt, that Bt brinjal is safe for human consumption and that its environmental effects are negligible. It is appropriate now to release Bt brinjal for cultivation in specific farmers' fields in identified states" (INSA, 2010a; INSA, 2010b; INSA, 2010c).
- As a follow up to the moratorium on Bt brinjal, MOEF constituted a committee comprising experts, scientists and members of GEAC and called on a meeting "Consultation with experts and scientist on regulatory process for Genetically Modified Crops as part of Bt brinjal post moratorium follow-up" on 27 April 2011. The committee recommended the "limited release of Bt brinjal seeds to identified farmers under strict expert supervision to evaluate its performance in public space."

- The meeting of scientific advisory council of PM (SAC-PM) on biotechnology and agriculture chaired by Bharat Ratna Prof. CNR Rao held on 9 October 2012 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 noted that a science informed, evidence-based approach is lacking in the current debate on biotechnologies for agriculture (PIB, 2012).
- Neighboring Bangladesh approved Bt brinjal event EE-1 for commercial cultivation on 30 October 2013 followed by distribution of Bt Brinjal seedlings to farmers on 22 January 2014. Bangladesh became the first pioneering country in the world to successfully cultivate Bt brinjal where 120 farmers reaped a bountiful harvest of Bt brinjal in 2014. Notably, India continues to deny their farmers' access to Bt brinjal while farmers in Bangladesh harvest benefits of the technology to control the menace of pest, the fruit and shoot borer (Choudhary, Nasiruddin and Gaur, 2014).

Besides Bt brinjal Event EE-1, GEAC has also approved the field trials of another Bt brinjal event developed by NRCPB and to be commercialized by Bejo Sheetal. GEAC's approval of field trials of Bt brinjal event opens up an opportunity for the Government of India to revisit the moratorium on Bt brinjal event EE-1 which was declared safe for environmental release by GEAC on 14 October 2009. The Government of India should prioritize the commercial approval of 16 varieties of Bt brinjal with event EE-1 developed by TNAU, Coimbatore; UAS Dharward and IIVR, Varanasi pending commercialization for five years now. Notably, the public sector investment in developing these varieties set to go to waste because seeds tend to lose their vitality with time (Sud, 2014). Table 17 lists 16 Bt brinjal varieties developed by three different public sector institutes in India.

Socio-Economic Benefits and Impact of Bt cotton in India

In 2014, 7.7 million small holder cotton farmers having an average land holding of less than 1.5 hectares benefited from planting Bt cotton over 11.6 million hectares equivalent to 95% of 12.25 million cotton area. Remarkably, a cumulative ~54 million small-holder cotton farmers planted Bt cotton in the

Table 17. Distribution of Bt brinjal Hybrids and OPVs

Mahyco's 8 Bt brinjal hybrids	Public Sector's 16 Bt brinjal open pollinated varieties (OPVs)		
	UAS, Dharward (6)	TNAU, Coimbatore (4)	IIVR, Varanasi (6)
MHB-4Bt	Malapur local (S)Bt	Co2-Bt	Pant Rituraj
MHB-9Bt	Manjarigota Bt	MDU1-Bt	Uttara
MHB-10Bt	Rabkavi local Bt	KKM1-Bt	Punjab Barsati
MHB-11Bt	Kudachi local Bt	PLR1-Bt	VR-14
MHB-39Bt	Udupigulla Bt	-	IVBL-9
MHB-80Bt	GO112 Bt	-	VR-5
MHB-99Bt	-	-	-
MHB-112Bt	-	-	-

Source: Analyzed and compiled by ISAAA, 2014 thirteen-year period showing a plausibly high repeat decision of planting of Bt cotton between 2002-03 to 2014-15. Notably, the increase from 50,000 hectares of Bt cotton in 2002, (when Bt cotton was first commercialized) to 11.6 million hectares in 2014 represents an unprecedented 230-fold increase in thirteen years. Provisional estimates by Brookes and Barfoot (2015, Forthcoming) indicate that India enhanced farm income from Bt cotton by US$16.7 billion in the twelve year period 2002 to 2013 and US$2.1 billion in 2013 alone, similar to 2012.

The field performance and socio-economic assessment of Bt cotton have been the integral part of the regulatory process of commercialization of Bt cotton in India. Until now, fourteen peer-reviewed research studies have been conducted over the years, three studies were conducted prior to the commercialization of Bt cotton from 1998 to 2001, whereas eleven studies were carried out to assess ex-ante impact of Bt cotton, which were reported during the post commercialization of Bt cotton from 2002 to 2013. 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). The summary and key findings of these fourteen studies conducted by public institutes on cost-benefits of Bt cotton were included in previous briefs, ISAAA Brief 26 to 46 released between 2002 to 2014. Readers are encouraged to refer to previous ISAAA briefs for more details about the socio-economic benefits of Bt cotton in India between 2002 to 2014.

Major Policy Developments on GM crops in India

Despite raging controversy by anti-biotech activists, there have been numerous initiatives to strengthen the regulatory system and raise public and policy makers understanding about GM crops in India. A summary of these initiatives are briefly described below;

- **NAAS Public Understanding Committee on Science:** The Indian National Academy of Agricultural Sciences (NAAS) conveyed a roundtable meeting on “GM Crops for Nutritional Security” under the chairmanship of Prof. M.S. Swaminathan on 12 February 2014 at the National Academy of Agricultural Sciences, New Delhi. NAAS unanimously passed a resolution endorsing application of biotechnology in agriculture. NAAS’ resolution included the setting up two committees for the purpose of educating public and politicians on “scientific facts” about GM crops. The resolution states that NAAS may set up two committees on the pattern set up by the Royal Society of London including first, the Committee on Public Understanding of Science and second, the Committee on Political Understanding of Science.

  The academy concurred that GM crop technology is a promising, relevant and efficient technology for low-input high-output agriculture for crop improvement where conventional breeding tools have not been effective. GM technology will be a tool to improve agricultural crops for their nutritional value, nutrient and water use efficiency, productivity, tolerance/resistance to biotic and abiotic stresses. The academy called on the Government of India to lift de facto moratorium on the field trials of GM crops (NAAS, 2014).

- **MOST DBT Launches Biotech Strategy:** The Department of Biotechnology of the Ministry of

Science and Technology has released the draft national biotechnology development strategy, 2014, suggesting improvement in the existing regulatory system. The "Biotech Strategy-II" pitches for a world class regulatory system which can build confidence among the civil society, farmers, consumers and scientific community. The Biotech Strategy-II has also outlined measures to achieve this vision and also details on the establishment of Biotechnology Regulatory Authority of India (BRAI). In addition, DBT's revised strategy of 'Vision 2020' highlighted how GM crops would help achieve "higher productivity and better quality food while reducing resource inputs" (DBT, 2014).

- **Biotechnology Regulatory Authority of India (BRAI):** The Department of Biotechnology of the Ministry of Science and Technology has been attempting to set up the independent, science-based and professionally-led biotechnology regulatory authority of India. BRAI aims at creating a world class regulatory system that is science-based, transparent, efficient and dedicated to the safety of consumers and environment. It is expected that the establishment of BRAI would build confidence among the civil society, farmers, consumers and the scientific community and a rigorous but transparent regulatory system will also boost the confidence of the industry in investing in the biotech sector. (DBT, 2014). The BRAI Bill was introduced by the Union Science and Technology Minister in the Lok Sabha of the Parliament of India on April 22, 2013 in order to establish BRAI to carry out the risk assessment of all biotech products and supervise field trials of genetically modified crops. The BRAI Bill 2013 was lapsed in the parliament in 2014 and needs to be reintroduced at the earliest to expedite setting up of the independent biotech regulator in the country. BRAI shall consist of a 17-member inter-ministerial governing board to oversee the authority's performance and a Biotechnology Regulatory Appellate Tribunal where BRAI decisions could be challenged. However, the commercialization of biotechnology products in agriculture and healthcare would be left to central and state Governments respectively (Biospectrum, 2014).

Political Will and Support to GM Crops in India

The new Government led by the Prime Minister Mr. Narendra Modi assumed office on 26 May 2014. His Government has emphasized revamping water and agriculture sector because it employs approximately 60% of the country's population. The Government is also very keen to boost farm growth, productivity and income of farmers. It promises to rationalize the approval system, cut down the cost of approvals, remove the redundant laws and improve transparency and accountability in the system. As a first step towards revamping agriculture sector, the Government of India has initiated programs to improve delivery of technology from lab to land, enhance capacity building and training of manpower, improve water efficiency by introducing the concept of "per drop more crop", improve soil health, create irrigation facility and revitalize the agricultural extension system. In particular, efforts are made to address concerns related to the supply of good quality seeds and introduction of biotechnology including GM crops to improve crop productivity and farmers' income. This Brief presents the excerpts from the top policy makers to demonstrate the political will and support to advance the field trials and introduction of new genetically modified crops in India.

India's President Mr. Pranab Mukharjee calls for an urgent need to dispel fears over GM crops.
India's President, Mr. Pranab Mukherjee called for greater awareness about genetically modified (GM)

crops to address public concerns. The President referred to the benefits that India has got through cultivation of Bt cotton and the wide adoption of GM crops, and he said there was a need to pursue these new technologies for the benefits they provide. ***"The development of transgenic crop varieties having the novel trait of insect resistance, herbicide tolerance and hybrid production has led to significant cultivation of GM crops. These crops currently occupy 170 million hectares in 28 developed and developing countries. In India, Bt cotton has boosted production and enhanced export earnings,"*** said the President during the inaugural of the conference of vice chancellors of agricultural universities, directors of ICAR and farmers in Baramati, Maharashtra on 19 Jan 2014 (ICAR, 2014).

India's Prime Minister Mr. Narendra Modi emphasizes on new science and technology interventions in agriculture. India's Prime Minister Mr. Narendra Modi called upon agricultural scientists to make the farming community more empowered and prosperous through new science and technology interventions. While addressing the occasion of ICAR 86th Foundation Day on 29 July 2014, the Prime Minister emphasized the need to disseminate technologies to farmers in the most simple, adoptable and acceptable manner. The Prime Minister Modi reiterated that ***"there is a need to have adequate improvements in science and technology in sync with fast changing climate and agro climatic zones. Scientists should win the confidence of farmers so that they adopt their technologies with hope."*** He exhorted agricultural scientists to work towards a two-fold objective – enable farmers to feed India's population and the world, and earn a good livelihood. The Prime Minister also envisions new mantra for agriculture "per drop, more crop" (ICAR, 2014a).

India's Union Agriculture Minister Mr. Radha Mohan Singh pitches for biotech crops. India's Agriculture Minister Mr. Radha Mohan Singh emphasized that biotechnology can help in replacing traditional methods of agriculture to boost quality and production. Highlighting the benefits of biotechnology, Minister Singh said that crops can be made climate resilient and drop in production can be addressed with use of biotech crops. In the backdrop of limited natural resources and growing population, there is an urgent need to change the traditional methods of agriculture, he added. Laying the foundation stone of Indian Institute of Agricultural Biotechnology (IIAB) Ranchi, Jharkhand, the Union Agriculture Minister, Mr. Radha Mohan Singh stated that ***"there is a need of bringing second green revolution, particularly, in eastern states of the country which were not covered earlier during first green revolution. He stated that with the opening of Biotech institute the provisions made for biotechnological education will pave a way for preparing trained human resource who will create awareness among farmers about the advanced agriculture by use of biotechnology technique along with traditional methods of farming."***

India cannot say No to science – Union Minister of State for Environment, Forest and Climate Change Mr Prakash Javadekar. Union Minister of State for Environment Mr. Prakash Javadekar stated that India cannot say no to science. Speaking at the launch of the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) titled 'IPCC AR5: What it means for stronger, more inclusive India' on 6 August 2014, he said, ***"We have not said no to science. Nobody can say no to science. Yes we have to take proper caution; we have to take proper action. But you cannot deny it. Nations that do not believe in science are on the path to backwardness. Science is dynamic and one must believe in it"*** (IBN, 2014). Mr. Javadekar said he was of the firm opinion that whichever country doesn't believe in science is doomed to fail and will be left behind. And the country that worships science cannot be left behind. And India has chosen the path of science, he added (The Hindu, 2014).

Minister of State for Agriculture, Dr. Sanjeev Kumar Balyan. The Minister of State for Agriculture and Food Processing Industries, Dr. Sanjeev Kumar Balyan, in response to Parliament Questions in the Lok Sabha told Parliament that ***"there is no credible scientific evidence proving that GM crops have adverse impact on environment, human health and livestock."*** Appending the response, he cited details of success of Bt Cotton in India and added that biotech crops have been grown in 27 countries. These biotech crops include soybean, maize, papaya, canola and tomato (Lok Sabha, 2014). ***"Government of India is following a policy of case-by-case approval of genetically modified crops. A GM crop is approved for commercial cultivation after a thorough evaluation of its bio-safety and agronomic performance by the review committee on genetic manipulation and Genetic Engineering Appraisal Committee (GEAC),"*** said Minister Balyan. He was responding to questions on any scientific evidence indicating adverse effects of GM crops and on the kind of corrective measures taken by the Government in this regard. Denying any health risk, the minister cited examples of countries like USA, Brazil, Argentina, Canada and China that cultivated as many as 25 GM crops on a total area of 175.2 million hectares in 2013.

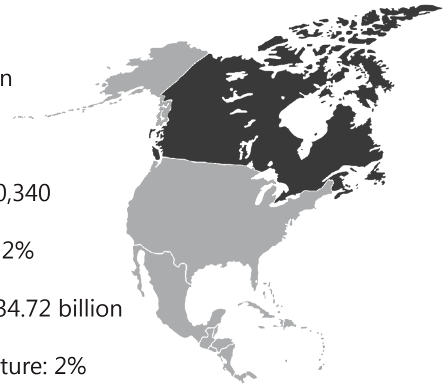
India, keen to accept genetically modified food crops, DBT Secretary Dr. K. Vijayraghvan. DBT Secretary Dr. K. Vijayraghavan stated that India needs to choose the technologies essential to address its food and nutrition issues while responding to live debate hosted by scidev.Net on 11 June 2014. Secretary Vijayraghvan believes that technology and science are key to food security and India is now more prepared than ever to accept genetically modified food crops. On the contentious issue of Bt brinjal in India, Dr. Vijayraghvan said ***"Bt brinjal is safe. It was not introduced in India, but it has been introduced by Bangladesh. There is no evidence for "natural cross-pollination and lateral gene transfer" of the Bt gene in any such contexts. But the question takes a non-problem, asks for a yes or no answer and makes a non-issue an issue."*** Responding over the moratorium on Bt brinjal he said ***"From a scientific and logical point of view, the precautionary principle is not one that seems meaningful here and not a 'reason' at all."*** He added that GM crops are safe and fears over contamination of regular crops unfounded, and India cannot ignore rapid changes taking place in the world of agricultural biotechnology (scidev.Net, 2014).

It would be Shameful if we let GM technology pass by, Dr. Sanjay Rajaram, World Food Prize Laureate 2014. Dr. Sanjaya Rajaram, global renowned wheat breeder and laureate of the World Food Prize 2014 emphasized that adopting new technology and innovations is the way to meet the challenge of feeding growing populations. Dr. Rajaram, who worked closely with the late Dr. Norman Borlaug developed hundreds of varieties of disease-resistant wheat and feeding millions across the world. In an exclusive interview to Financial Express in July, 2014 he said ***"Adopting new technology and innovations is the way to meet the challenge of feeding growing populations. We need the best technology to enhance productivity of our agriculture. It would be shameful if we let GM technology pass. Investment in GM crops will help enhance the capacities of crops against drought, heat, flooding and salinity"*** (Financial Express, 2014).

CANADA

In 2014, Canada is fifth place in world ranking of biotech crops with biotech crop hectarage at 11.6 million hectares compared with 10.8 million hectares in 2013 – a 7% increase, mainly due to an increase in hectarage of canola and soybean. The four biotech crops grown in Canada in 2014 were canola, maize, soybean and sugar beet. Biotech hectares for soybean and canola were significantly higher whereas biotech maize was slightly lower in 2014; biotech sugar beet hectarage was the same as 2013. Canada is provisionally estimated to have enhanced farm income from biotech canola, maize and soybean by US$5.6 billion in the period 1996 to 2013 and the benefits for 2013 alone is estimated at US$958 million.

CANADA



Population: 34.3 million

GDP: US$1,736 billion

GDP per Capita: US$50,340

Agriculture as % GDP: 2%

Agricultural GDP: US$34.72 billion

% employed in agriculture: 2%

Arable Land (AL): 47.8 million hectares

Ratio of AL/Population*: 6.0

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

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

Total area under biotech crops and (%) increase in 2014:
11.6 Million Hectares (+7%)

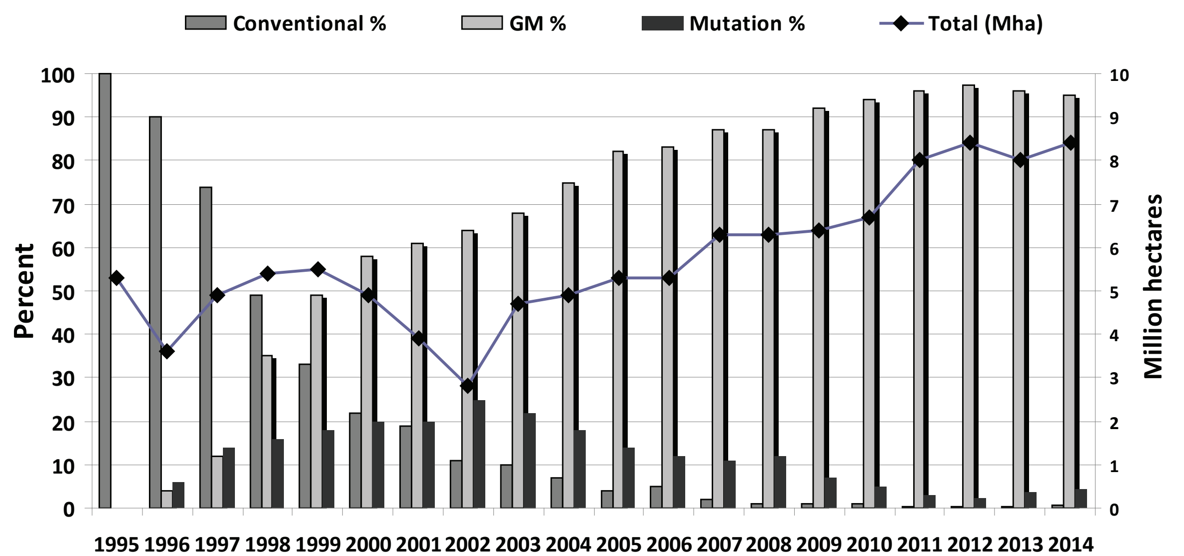
Farm income gain from biotech, 1996-2013: US$5.6 billion

*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 2014, Canada is fifth place in world ranking of biotech crops with an area of 11.6 million hectares, up by 7% from 2013. The four biotech crops grown in Canada in 2014 were canola, maize, soybean and sugar beet, with herbicide tolerant canola being the major biotech crop at 8.0 million hectares and a high 95% adoption rate, biotech soybean at ~2.2 million hectares, biotech maize at 1.4 million hectares, and herbicide tolerant sugar beet at 15,000 hectares.

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 at 95%. The total land area planted to canola in Canada in 2014 was 8.4 million hectares, up from the 8.0 million hectares in 2013. In 2014, the national adoption rate for biotech canola was 95% marginally down from 96% in 2013, this compares with 96% in 2011, 94% in 2010, 93% in 2009, 86% in both 2008 and 2007, 84% in 2006 and 82% in 2005 (Figure 18). In 2014, biotech herbicide tolerant canola was grown on 8.0 million hectares, compared with 7.8 million hectares in 2013, 8.4 million hectares in 2012, 7.7 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

Figure 18. Percentage of Conventional, Biotech and Mutation-based Herbicide Tolerant (HT) Canola Plated in Canada, 1995 to 2014 (Million Hectares)



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 canola hectares, and also in the percentage adoption to herbicide tolerant biotech canola, which reached a record high national adoption rate of 97.5% in 2012. In 2014, biotech canola was estimated at an adoption rate of 95%; mutation based canola at 4.3% and conventional at 0.8% (Personal Communication Canola Council of Canada 2014).

In Ontario and Quebec, the major provinces for maize and soybean, total plantings of maize for all purposes in 2014 were 1.5 million hectares and 2.3 million hectares for soybean. In 2014, the area of biotech maize, was 1.4 million hectares (93% adoption), down slightly from last year, which was 97.6%. Canada is one of only nine countries (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 2014, only 4% contained a Bt gene, 16% are herbicide tolerant and Bt/HT products are 80%; this is similar to 2013 when stacks were approximately the same, 79% in 2012, 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.

Biotech RR®sugar beet was planted in Canada in 2014, after being launched in 2008. It is estimated that in 2014, 96% (similar to 2013) of the sugar beet in Canada, equivalent to approximately 15,000 hectares were RR®sugar beet. This was the seventh 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.

On 26 April 2013, the Canadian Food Inspection Agency (CIFA, April 2013) issued a press release confirming that it registered a variety of RR®alfalfa – this allows Gold Medal Seeds, a subsidiary of Forage Genetics International LLC to sell the seed of this variety commercially in Canada. At the time when this Brief went to press, to ISAAA's knowledge, no further details were available regarding commercialization which has not yet been initiated in Canada, despite approval of the product in Canada. It is estimated that approximately 2% of the Canada canola production will be used for biofuel by 2014. 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.

In 2014, Canada approved HT VCO-01981-5 maize and HT + IR Mon 89034 x TC1507 x NK603 x DAS40278 maize for cultivation.

Benefits from Biotech Crops in Canada

In a provisional data, Canada is estimated to have enhanced farm income from biotech canola, maize and soybean by US$5.6 billion in the period 1996 to 2013 and the benefits for 2013 alone is estimated at US$958 million (Brookes and Barfoot, 2015, Forthcoming).

An 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 18). 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.

The findings of the survey were similar to earlier studies (Canola Council of Canada, 2007) where 650 growers were considered, 325 of them growing conventional and the other half growing herbicide tolerant biotech canola, during the period 1997 to 2000. Results showed that planting biotech canola brings reduction in herbicide cost by 40%; 10% yield advantage; increased grower revenue of US$14.36 per hectare and a profit of US$26.23 per hectare; and a total direct and indirect value to industry and growers of US$464 million.

The Economic Impact of Canola on the Canadian Economy released in 11 October 2013 by Canola Council of Canada (CCC) (2013) reports the tremendous growth in canola's contribution to the

Table 18. 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.

Canadian economy, which equates to Ca$19.3 billion, which also directly or indirectly accounts for 249,000 Canadian jobs.

The report commissioned to a leading agri-business research firm LMC International by CCC and the Agriculture and Agri-Food Canada of the Agriculture and Agricultural Flexibility Fund, is a part of the Canola Market Access Plan. The Report is based on the best practices to estimate the total benefits derived from Canadian-grown canola from farm to market, in three crop years 2009 to 2012. The analysis showed that canola's total contribution to the Canadian economy has more than doubled in less than a decade and Canadian wages created by the canola industry have more than tripled (Table 19). Wages linked to the industry's impact have more than tripled during the same period.

Other Developments in Biotech Crops

The Governments of Canada, and Saskatchewan, and the University of Saskatchewan created the Canadian Wheat Alliance (CWA), an initiative to coordinate research and development projects to improve wheat varieties by reducing losses due to extreme weather conditions such as drought, heat, cold, and diseases. The CWA invested approximately Ca$97 million over the first five years to support wheat improvement research, advance Canada's wheat crops, and ensure its global competitiveness through the combined expertise of the National Research Council of Canada, Agriculture and Agri-Food Canada, the Government of Saskatchewan and the University of Saskatchewan (Crop Biotech Update, 22 May 2013).

Genetically modified (GM) purple tomatoes developed by John Innes Centre (JIC) scientists in the UK are being harvested in Ontario, Canada, for future research and to attract private investors. The harvest from the 5,000 square-foot glass house will yield GM tomatoes to produce 2,000 liters of purple tomato juice. It will be used to generate new research and industry collaborations and to start the process of seeking the regulatory authorization needed to bring a commercial juice to market. The tomatoes derive their color from high levels of anthocyanins and have been shown to have anti-inflammatory effects compared to regular ones and slow down the progression of soft-tissue carcinoma in cancer-

Table 19. Canola's Total Economic Impact* on Wages and Jobs, 2004/05 to 2011/12

Items	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	Annual Average 2009/10 to 2011/12
Economic Impact ($ Billion)	$6.998	$7.474	$9.680	$16.067	$14.327	$15.346	$21.287	$21.161	$19.264
Jobs	194,258	177,144	201,856	198,343	192,623	241,397	244,984	260,587	248,989
Wages ($ Billion)	$3.439	$3.754	$5.709	$7.568	$8.008	$10.294	$12.671	$14.568	$12.514

* Including direct, indirect and induced impact

prone mice. They have also doubled the shelf life of regular tomatoes (Crop Biotech Update, 29 Jan 2014).

Farmer Support

Grain Growers of Canada and its more than 50,000 farmer members said they support genetically modified crops.

"We support Canada's robust science-based regulatory environment which ensures any new crops or traits are proven safe for human consumption, animal feed and our environment," the association's president, Stephen Vandervalk, said in a media release. "While we appreciate that many long-time opponents of progress have concerns, the reality is they have a lot of rhetoric, but no facts to back up their case."

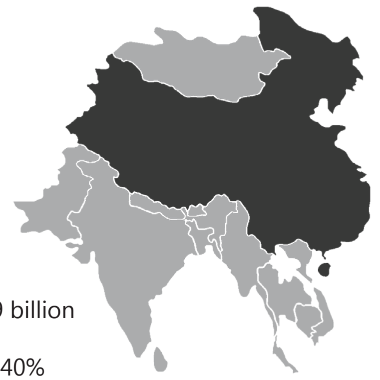
Canadian Forage and Grassland Association, said genetically modified alfalfa should present "few issues" to conventional livestock producers growing alfalfa for their own use. The association does say that "the greatest potential negative impact of genetically-modified alfalfa would be for organic producers and seed growers, especially those that sell to the organic market or to the European Union where genetically engineered seeds are not permitted."

Lady Farmer Cherilyn Nagel farms in Saskatchewan, talks about life on the farm, her passion for agriculture, the value of modern technology and the safety of food produced on Canadian farms. "Through the use of biotech seeds, I was able to increase my yield 20 to 50% higher than before, I do not worry about pests and there is tremendous benefit on the safety of the food environment."

CHINA

In 2014, 7.1 million small farmers (0.5 to 0.6 hectare/farm) successfully planted 3.9 million hectares of biotech cotton at an adoption rate of 93% of its 4.2 million hectares total cotton hectarage. In addition, ~8,000 hectares of virus resistant papaya were planted in Guangdong, Hunan Island and this year's new province of Guangxi; plus ~543 hectares of Bt poplar, the same as last year. Despite China's decreased total cotton hectarage from 4.6 million hectares in 2013 to 4.2 million hectares in 2014 (mainly due to lower prices and high stockpiles of cotton in China), biotech cotton adoption has increased from 90% in 2013 to 93% in 2014. Impressively, virus resistant papaya plantings increased by ~50% from 5,800 hectares in 2013 to 8,475 hectares in 2014. In addition to the 7.1 million farmers benefiting directly from biotech Bt cotton there may be an additional 10 million secondary beneficiary farmers cultivating 22 million hectares of crops which are alternate hosts of cotton bollworm and benefit from decreased pest infestation due to the planting of Bt cotton. Thus, the actual total number of beneficiary farmers of biotech Bt cotton in China alone may well exceed 17.1 million. Provisional data on economic gains at the farmer level from Bt cotton for the period 1997 to 2013 was US$16.2 billion and US$1.6 billion for 2013 alone.

CHINA



Population: 1,347.6 million

GDP: US$7,319 billion

GDP per Capita: US$5,450

Agriculture as % GDP: 10%

Agricultural GDP: US$731.9 billion

% employed in agriculture: 40%

Arable Land (AL): 113.8 million hectares

Ratio of AL/Population*: 0.4

Major crops:
- Rice, paddy
- Sugarcane
- Sweet potato
- Maize
- Vegetables, fresh
- Cotton

Commercialized Biotech Crops:
- Bt Cotton
- Bt Poplar
- PRSV Papaya
- VR Sweet Pepper
- DR, VR Tomato

Total area under biotech crops and (%) increase in 2014:
3.9 Million Hectares (-7%)

Increased farm income for 1997-2013: US$16.2 billion

*Ratio: % global arable land / % global population

Bt maize, and Bt rice, offer significant benefits and have momentous implications for China, Asia and the rest of the world in the near, mid and long term, because rice is the most important food crop and maize the most important feed crop in the world. China's research and commercialization of Bt maize, herbicide tolerant maize and phytase maize as well as Bt rice, will be very important potential contributions to global food and feed needs, and that of China. Whereas President Xi Jinping has endorsed the technology that is used in biotech soybean and maize imported by China in very large quantities (63 million tons of soybean and 3.3 million tons of maize in 2013), domestic production of

these biotech crops has not been implemented to-date. President Xi at the Communist Party Conference in December 2013 stated that, because the technology is new "*it's reasonable that society should hold controversial views and doubts.*" Importantly, China's Ministry of Agriculture has launched a large national public information media campaign to increase the awareness of the public regarding the multiple and significant benefits that biotech crops offer China. Continuing high priority to R&D support for biotech crops in China reflect the country's long term commitment to the safe use of biotech crops. China imports increasing quantities of maize, most (90%) of that is biotech and consumes one-third of global soybean production. China imports 65% of global soybean imports, over 90% of which is biotech.

Since 1997, China has been planting large hectarages of Bt cotton and small hectarages of GM papaya, poplar and other vegetables. In 2009, biosafety certificates were issued for Bt rice and phytase maize (Table 20). China has successfully planted Bt cotton since 1997, and in 2014, 3.9 million hectares were planted to biotech cotton at adoption rate of 93% compared to 90% adoption in 2013. Less total hectarage of cotton at 4.2 million hectares was planted in 2014 compared with 4.6 million in 2013, and this was the reason for lower hectarage of Bt cotton in 2014. The decrease in total hectarage is linked to global stabilization of cotton prices and demand. In addition to cotton, China also grew virus resistant papaya, which increased in hectarage by 46%, from 5,800 hectares in 2013 to 8,475 hectares in 2014. Papaya growing regions Guangdong province and Hunan Island were joined by Guangxi province in 2014. Bt poplar has been cultivated in 2003, and in 2013 and 2014, a total of 543 hectares were planted in China.

Progress on Bt Cotton Adoption in China

Similar to 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 2014, at 4.2 million hectares was lower than that planted in 2013 at 4.6 million hectares, but the adoption rate increased to 93% in 2014, thus, offsetting the decrease in total area of cotton. The decrease in national cotton hectarage is probably due to China's implementation of a target price program for cotton and soybean in late January to lower prices when stockpiles of cotton in China were large. Despite significant stockpiles, biotech cotton adoption increased from 90% in 2013 to 93% in 2014. It is estimated that global hectarage of cotton will stabilize at about 33 million hectares in 2014/2015 (ICAC, 2014).

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 7.1 million small and resource-poor farmers grew 3.9 million hectares of Bt cotton in China in 2014. 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. A paper by Hutchinson (2010) based on studies in the USA draws similar conclusions to Wu et al. (2008) – 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.

Table 20. GM Events Approved for Cultivation in China

Year Approved	Crop	Event Name	Developer	Trait Type	Trait
1997	Tomato	Huafan No 1	Hainan Agricultural University (HAU)	Single	PQ
1997	Cotton	GK12	Chinese Academy of Agricultural Science	Single	IR
1998	Poplar	Bt poplar	Research Institute of Forestry	Single	IR
1998	Sweet Pepper	PK-SP01	Beijing University	Single	DR
1998	Petunia	Petunia-CHS	N/A	Single	PQ
1999	Cotton	SGK321	CAAS	Stacked	IR
1999	Tomato	PK-TM8805R	Beijing University	Single	PQ
2001	Poplar	Hybrid poplar clone 741	RIF	Stacked	IR
2006	Papaya	Huanong No. 1	South China Agricultural University	Single	DR
2009	Maize*	BVLA430101	Origin Agritech	Single	PQ
2009	Rice*	Huahui-1	HAU/Origin Agritech	Single	IR
2009	Rice*	GM Shanyou 63	HAU/Origin Agritech	Single	IR

Source: Compiled by ISAAA, 2014
*Field trialed and given biosafety certificates
PQ - Product Quality, IR - Insect Resistance, DR - Delayed Ripening

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 are alternate host of 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. 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.

This dramatic reduction by 90% in the level of cotton bollworm in alternate host crops has implications for insecticide savings, which may translate to a significant decrease in the need for insecticide sprays on these host crops, 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 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."

After Bt cotton was introduced in the market in 1996, the area of Bt cotton has increased more than 12 times from 0.26 million ha in 1998 to 3.8 million hectares in 2008. The adoption rate indicated that till 2008, ~75% of cotton area was Bt cotton adapted to local production conditions. According to Wang et al (2013), adoption rate at the provincial level as shown in Figure 19 also presents the following production conditions:

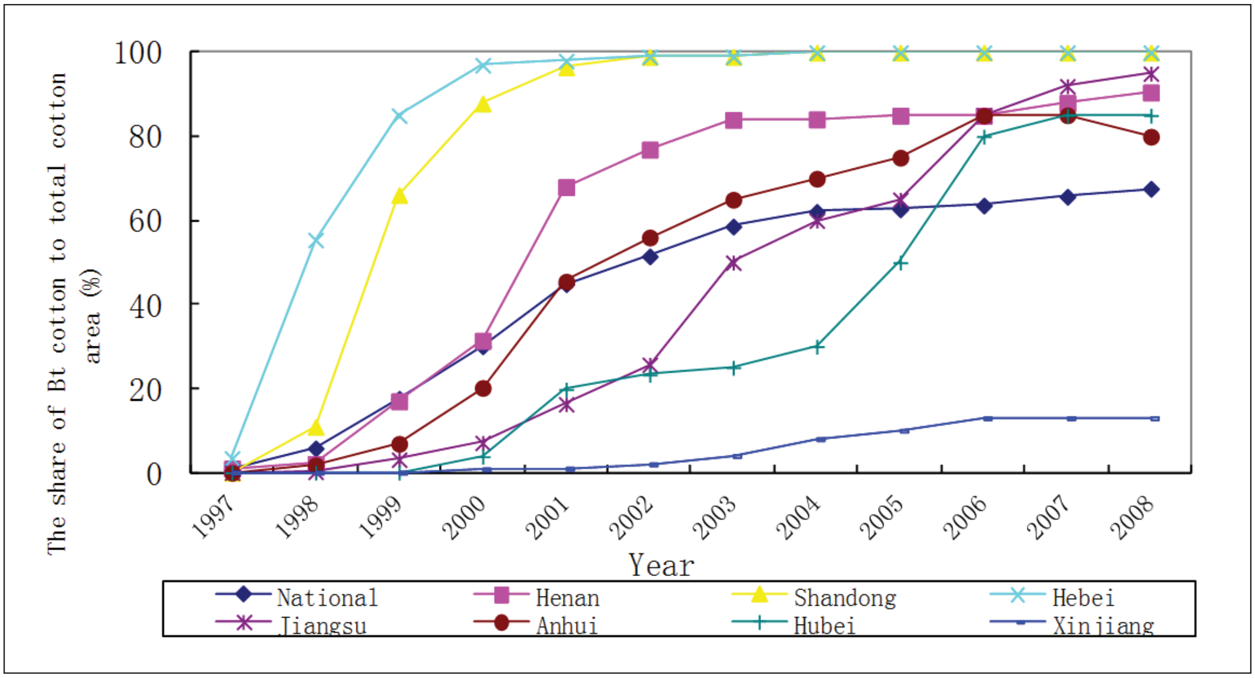
Firstly, is the regional variation of adoption as exemplified in 1997, when the share of Bt cotton in Huang-Huai-Hai cotton production zone was only 5% and none in Yangtze river and Xijiang zones. One year later, the share of adopted area increased to 42.9% in Huang-Huai-Hai zone and 2.6% in Yangtze River zone (Huang et al., 2010). Even though Bt cotton has been commercialized in Xinjiang since 1999, the adoption rate there was still low at 13% due to less pest pressure in 2008. The adoption of Bt cotton mainly happened in Huang-Huai-Hai and Yangtze River cotton production areas.

Secondly, variation in regional adoption rate is based on the rate of commercial release. Thus, even though five provinces were allowed to cultivate Bt cotton at the same time, the adoption rate in Hebei and Shangdong provinces was faster than those in other provinces. Till 2000, the percentage of Bt cotton area to total cotton area was only 20% and less than 5% in Anhui and Hubei province. The commercial release of Bt cotton in Henan was one year lag than that in the first region, however, adoption grows at a faster rate than the average adoption rate at national level. The almost complete adoption of Bt cotton also happened in Hebei and Shangdong provinces dates back to 2003.

Thirdly, there appeared to have an inverse correlation of adoption and the infestation level of cotton bollworm after the commercial release of Bt cotton in China. That is the higher the infestation level of cotton bollworm, the faster is the adoption of Bt cotton, and vice versa. That is true across provinces. However, the adoption of Bt cotton is not correlated with the infestation levels of cotton aphid and cotton mirids.

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

Figure 19. The Adoption Rate of Bt Cotton by Provinces, 1997-2008



Source: Huang et al. (2010).

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.

In October 2013, it was reported that China had developed a new cotton variety, named Zhongzhi 2, which is resistant to three major pests: verticillium wilt (causes loss of 10 to 15% in yield), cotton bollworm and bacterial blight (Cotton 24/7, 9 October 2013). China currently plants 3.7 million hectares of Zhongzhi varieties and these are estimated to contribute US$2 billion per annum to the Chinese economy.

To further improve insect pest resistance of cotton, scientists at Huazhong Agricultural University in China used gene stacking strategy. *Cry9C* gene from *Bacillus thuringiensis* was introduced into cotton (cultivar Simian-3) through *Agrobacterium*-mediated transformation. The integration and expression of the gene were confirmed by PCR and RT-PCR. The transgenic plants exhibited moderate toxicity to cotton bollworm (*Heliothis armigera*) but strong toxicity to cotton leafworm (*Spodoptera litura*) compared with the transgenic plants expressing *cry 1Ac*. Then they pyramided *cry9C* gene and *cry 2A* or *cry 1Ac*, respectively by sexual crossing. Results showed that the expression of Cry9C protein in the progenies of the first generation had a similar level as the parent plants indicating the high heritability of Bt genes. Progenies from both Cry9C x Cry 2A and Cry9C x Cry 1Ac crosses showed better resistance to cotton leafworm than their parents. Based on the results, successful incorporation of gene pyramiding technology can provide a new solution of developing multiple resistance management strategies (Crop Biotech Update, 6 August 2014).

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 20). 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 4,500 hectares of papaya is now biotech papaya, resistant to the lethal papaya ring spot virus (PRSV) disease. In 2012, virus resistant papaya was grown for the first time in Hainan Island. It is where 60% of 4,000 hectares of biotech papaya was grown in 2014. Guangxi province planted their first biotech papaya with an initial 90% adoption of their 2,000 hectares. Thus, a country total of 8,475 hectares of biotech papaya were planted in 2014, a 46% increase from 5,800 hectares in 2013 (Personal Communication, Prof Li, South China Agricultural University).

Biotech Insect Resistant Poplar

Bt poplar has been cultivated in 2003, in 2013 and 2014, a total of 543 hectares were planted in China. This will help supply the estimated 330-340 million cubic meters of timber that China needs in 2015. In order to further 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 by the Research Institute of Forestry in Beijing, which is part of the Chinese Academy of Forestry. The first Bt poplars were developed and commercialized in 2003. More specifically, *Populus nigra* clones 12, 172 and 153, were developed with *cry1Aa* and a hybrid white poplar, clone 741, was transformed with a fusion product of *cry1Aa* and API coding for a proteinase inhibitor from *Sagittaria sagittifolia*. 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. By 2008, 400 hectares were planted, and this increased to 447 in 2009, 453 in 2010 (although the 30 hectare plantation in Huairou, Beijing was felled in 2011). Six hectares of 490 transgenic poplars were harvested in Manasi Plain Forest Station, Xinjiang Uygur Autonomous Region in 2011. Nearly 7 hectares of seedlings of the commercialized transgenic *P. nigra* transformed with *cry1Aa* were grown in 2011. 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. With the harvesting of 6 hectares of the 490 hectares and the planting of an additional

7 hectares, a net gain of 1 hectare for a total of 491 hectares of mature Bt poplars were planted in China in 2012. In 2013, the hectarage of Bt poplars increased slightly from 491 to 543 hectares due to additional plantings of 50 hectares of Bt black poplar (*P. nigra*) in Xingtai Handan, Hebei province and 2 hectares of transgenic white hybrid poplar in Ninghe and Tianjin. In 2014, 543 hectares, similar to 2013 were planted in China.

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.

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 21) 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".

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

Table 21. 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.

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.

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 area sites for the field 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.

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.

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). 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 stem 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 tonnes 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 tones of paddy annually, equivalent to one third of global production of approximately 750 million tonnes.

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 was 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 could 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 (Science Insider, 20 August 2014).

Whereas President Xi Jinping has endorsed the technology that is used to import biotech soybean and maize imported by China in very large quantities (63 million tons of soybean and 3.3 million tons of maize in 2013) domestic production of these biotech food crops has not been implemented to- date. President Xi stated at the Communist Party Conference in December 2013 that, because the technology is new ***"it's reasonable that society should hold controversial views and doubts,"*** (Bloomberg News, 9 October 2014). Importantly, China, through the Ministry of Agriculture, has launched a large national public information media campaign to increase the awareness of the public regarding the multiple and significant benefits that biotech crops offer China. Continuing high priority to R and D support for biotech crops in China reflect the country's long term commitment to biotech crops. China imports increasing quantities of maize, most of that is biotech, and consumes one-third of global soybean production. China imports 65% of global soybean imports, over 90% of which is biotech.

There are a growing number of collaborative initiatives between local and foreign institutions and companies. 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 CropScience 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.

China, the most populous country in the world is also the largest consumer of edible soybean in the world. China spent US$29 billion importing US soybean in 2007 which accounted for 38% of all US soybean exports. Collaborations for import of RR2Yield™ soybean to China started in 2008 – the product had already been approved as safe for food, feed in 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%). In 2014, China has imported more than 444 million bushels of the 2014/2015 crop.

In June 10, 2013, China's Ministry of Agriculture eventually approved three GM soybean products for importation as food that included Monsanto's Intacta™ RR2™, BASF's CV127™ and Bayer's Liberty Link™. This move by China is a manifestation of the government's confidence on the food safety of these biotech crops after months of delay during the first quarter of the year (Reuters, 10 June 2013). And in 2014, China, the world's second largest corn consumer, has renewed safety certificates for imports of three biotech varieties of the grain. Previously approved varieties are subject to safety review and authorization renewal every three years. China imports almost all its maize from the United States, the world's largest grower of biotech corn. The biotech corn events approved for import in China are the following: MON810, MON863, NK603, MON88017, MON89034, MON87460, Bt176, Bt11, MIR604, GA21, Bt11xGA21, 3272, TC1507, 59122, and T25 (Crop Biotech Update, 22 January 2014).

With continued partnerships, scientists at Hainan University and Hunan Provincial Academy of Agricultural Sciences are developing high yielding salt tolerant rice. Initial results showed that the biotech rice could provide six tonnes per hectare yield. In a field trial of 18 varieties in 3mu (0.2 hectare) in saline-alkali soils in eastern Jiangsu province, one variety exhibited similar output as varieties growing in normal farmland, upon harvest in October 2013. University professor Lin Qifeng also added that the experimental plantation was expanded to 100mu in 2014 to further evaluate the performance of the salt tolerant rice varieties (Crop Biotech Update, 8 January 2014).

Benefits from Biotech Crops in China

In 2013, Bt cotton was planted by 7.1 million small and resource-poor farmers on 3.9 million hectares, which is 93% of the 4.2 million hectares of all cotton planted in China in 2014. It is estimated provisionally that China has enhanced its farm income from biotech cotton by US$16.2 billion in the period 1997 to 2013 and by US$1.6 billion in 2013 alone (Brookes and Barfoot, 2015, Forthcoming).

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.

Support for Biotech Crops in China

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, China has an impressive portfolio of a dozen other biotech crops being field-tested, including maize, 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 crop. In June 2008, former **Chinese Premier Wen Jiabao** addressed the Chinese Academy of Science and stated that, ***"To solve the food problem, we have to rely on <u>big science</u> and technology measures, rely on biotechnology, and 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.

In 2013, the press and senior members of the scientific community have been more vocal in their support for biotech crops, as exemplified in the next paragraphs, including petitioning the Chinese government for early commercialization of biotech crops in China.

An article in the South China Morning post on Time to modify our stance on GM food published on 28 May 2013 is an example of a balanced article on biotech crops that poses relevant questions (Lo, 2013). Lo questioned whether opponents of biotech crops ***"can still be so misguided and have been stuck in a time-warp since the late 1990s, a time when there were understandable public concerns about GM's potential threat to human health and the environment."*** He pointed out that after two decades, hundreds of millions have eaten GM food, and that ***"any opposition is ideological, nothing more".*** He asked ***"How many actual food crises have been caused by GM products in the past two decades? Exactly zero."*** He concludes ***"that genetic modification (of crops) are at least as safe, if not safer, than conventional crop growing and that there have been many allegations but no proven cases despite many allegations."***

In July 2013, senior Chinese biologists petitioned the Chinese central government to assign high priority to biotech/GM/crops in China. Dr. Li Ning, an academician from the Chinese Academy of

Engineering and professor at China Agricultural University confirmed that more than 61 academicians from the Chinese Academy of Sciences and the Chinese Academy of Engineering signed the petition that was submitted to the government. Dr. Li noted that China is one of the largest consumers of biotech crops in the world but depends on imports, as opposed to growing its own; this is considered to be an “extremely grave” situation. The Chinese government subsidizes Chinese soya farmers heavily, but they only produce about 12 million tons of non-biotech soybean every year, and their products are “uncompetitive.” Since China grows only biotech cotton at a large scale, this poses a threat to food security, especially when international food prices begin to rise, said Dr. Dafang Huang, a researcher from the Biotechnology Research Institute at the Chinese Academy of Agricultural Sciences. Dr. Zhang Qifa, professor at Huazhong Agricultural University and academician at the Chinese Academy of Sciences, said that 61 academicians signed the petition in July and asked the Ministry of Agriculture to push for the planting of GM rice. The two kinds of biotech rice developed by his university were certified as safe by the Ministry of Agriculture in 2009. The certificates expired on August 17, 2014 and unfortunately were not renewed (Science Insider, 20 August 2014). In order to commercialize biotech crops in China, crops need two certificates: one for safety and the other for commercialization. Both Drs. Huang and Li said that biotech products certified by the ministry are safe to consume, which is consistent with science-based assessments made by Academies of Science world.

An article that appeared in the Wall Street Journal (23 October 2013) on *China pushing genetically modified food* speculates that China, caught between the need to increase food production and concerns about GM crops, is supporting a public education initiative that would “pave the way” to facilitate commercialization of home-grown GM crops in the country. It notes that the Ministry of Agriculture and other State agencies have recently been vocal in support of the technology. China’s official news agency, Xinhua, has reported on various events, ranging from publishing China’s success in sequencing the cucumber genus (published in the prestigious journal Nature) to covering a public “GM rice tasters” (apparently involving up to 300 people) featuring a variety of Golden Rice developed at Hebei’s premier university in Huazhong. The University has been organizing these “tasters” in more than 20 cities in Hebei Province. The Government has also been more active in interacting with those opposed to GM crops and stressing that they are safe. Coincidentally, senior academicians have petitioned Government to expedite industrialization/commercialization of home-grown biotech crops developed in China so that they can contribute to China’s food security goals. They also pointed out that for years China has already been importing large tonnages of GM soybean, canola and more recently maize for feed. China has 13 billion poultry and 500 million swine to feed. More generally the Ministry of Agriculture is seen by many to be more actively promoting the “industrialization” of GM crops and accelerating the passing of the necessary regulatory amendments. Given the current challenges facing China in terms of:

- demand for increased food and feed supplies to meet the needs of an increasingly more affluent meat-consuming society in China;
- more awareness and moral justification voiced by western media and public for the near-term approval of Golden Rice in the Philippines to combat blindness and mortality of children suffering from vitamin A deficiency; and
- increasing global concern regarding food security and climate change.

The above may support and facilitate changes in GM policy on the planting of more GM crops in China which currently include home-grown cotton and papaya.

The Central Committee of the Communist Party of China and the State Council issued its first policy document for 2014 on January 19, underscoring more rural reforms and planning for the development of modern agriculture. Hence, it is dubbed the "No.1 Central Document" for 2014 – the 11th year of its issuance and is focused on agricultural issues. The document listed eight aspects and 33 points for detailed government work on reforms related to the "three rural issues" – agriculture, rural areas and farmers. China puts improvements in national food security system at the top of the reform list for 2014, as well as in the next few years. It will also promote technological innovation in the agricultural sector, develop modern seed industry and promote the mechanization of agriculture (Crop Biotech Update, 19 February 2014).

In support of biotechnology, **Agriculture Minister Han Changfu** told a press conference of the annual session of the National People's Congress (NPC), Chinese top legislature, on March 6, 2014 that he himself eats genetically modified (GM) food, mainly soybean oil. ***"Whether the GM is safe or not should not be decided by departments or individuals, it should be decided by scientists following strict standards and procedures,"*** Han said. ***"Chinese soybean oil is mainly processed from imported GM soybean, which has passed the safety assessment of producing country and strict validation of Chinese National Security Committee of Genetically Modified Organisms,"*** Han added. He stressed that China has established laws and regulations which cover transgenic research, production, processing, marketing and import licensing as well as mandatory product identification. The minister reiterated China's position on transgenic technology that the country must strive to keep up with the world's advanced level and that it must possess its own intellectual property rights (Crop Biotech Update, 19 March 2014).

Adoption and Uptake Pathways of Biotech Cotton in China

ISAAA commissioned a study on Adoption and Uptake Pathway of GM Technology by Chinese Smallholders: Evidence from Bt Cotton Production with authors: Wang Xiaobing, Jikun Huang, Huaiju Liu, Cheng Xiang and Wei Zhang in 2013. The study's conclusion and recommendations are presented below.

> China is one of the first countries that have commercialized GM crops. Bt cotton was commercially released in 1997 and has been rapidly adopted by farmers thereafter. Our survey shows that adoption rate of Bt cotton reached nearly 100% by the early 2000s in Huang-Huai-Hai region, a major cotton production region in China. Bt cotton is well reported as a successful case of biotechnology adoption in China.
>
> The introduction of Bt cotton had helped millions of small farmers to recover their cotton production in the late 1990s. Even though China has a long history of cultivating cotton due to breakout of cotton bollworm in the middle 1990s, the cotton area shrank. With the availability of Bt cotton for farmers, in majority of sampled counties, the share

of cotton area to total sown area increased parallel with the diffusion of Bt cotton.

Bt cotton technology is neutral technology that benefited all farmers. Farmers in Huang-Huai-Hai region were all smallholders with average cultivated land area of less than one hectare. Field work of both Bt cotton and non-Bt cotton were mainly conducted by women as men engaged off-farm job more than women. Such reducing pesticide use and saving labor due to Bt cotton adoption benefited women. There were no significant differences in household characteristics between Bt cotton adopters and non-Bt cotton adopters.

However there was spatial pattern of Bt cotton production evolution. It started in Huang-Huai-Hai region and then followed by Yangtze River cotton production region. This spatial evolution was closely correlated with serious local pest problem (e.g., bollworm), the nature of biotech crop, and biosafety regulation.

As all cotton farmers are smallholders in China, all of them gained significantly from adoption of Bt cotton. Major benefits of planting Bt cotton include the reduction of insecticide use, mitigating yield loss from bollworm attacks (or increase yield), and saving labor inputs in cotton fields. As the cotton farmers are also relatively poor, Bt cotton also significantly improved their income and livelihood.

Our analyses show that in the first stage of Bt cotton diffusion, both seed companies and the technology developers played important roles in farmers' use of Bt cotton. Seed companies and technology developers (e.g. research institutes or biotech companies) conducted Bt cotton field trials in cotton production villages where farmers often became the first adopters of Bt cotton varieties. Technology developers also arranged Bt cotton field demonstrations in major cotton production regions, which helped the early adopters' understanding and interested in the technology.

Meantime, local public agricultural extension technology extension staff (or technicians) and leading farmers were also important facilitators in the initial stage of Bt cotton adoption. For example, some local extension technicians invited farmers to visit Bt cotton trial fields or demonstration fields of technology developers. In some villages, coordinated by village leaders, training workshops on Bt cotton or visiting Bt cotton field trials were provided for farmers who became the first adopters of Bt cotton. Some village leaders also coordinated the Bt cotton seed generation and set up the seed purchasing contract with the local seed company, which helped their villagers to become the first adopters and facilitated future expansion of Bt cotton in the villages. With the outstanding performance of Bt cotton by it's first adopters, the other farmers in the same village followed up rapidly. Generally, farmers visited the Bt cotton fields of the first adopters and learned the advantages of the technology. The followers also learned and adopted Bt cotton from their neighbors, other farmers inside or outside their villages or the hometown of the wife.

However, it is worth noting that when Bt cotton was first released, there were serious constraints in its adoption. Many farmers wanted to plant Bt cotton but the supply of Bt cotton seed did not meet their demand. Because most Bt cotton varieties were conventional (or not hybrid), lack of seed availability was overcome by many farmers by using own saved seeds or getting seeds from other farmers who planted Bt cotton in the previous year. Availability of Bt cotton seed in new province was also subjected to biosafety regulations because approval of Bt cotton in China is case-by-case and region-by-region. In addition, our study also shows that with the limited knowledge about biotechnology, some farmers delayed their adoption.

The results of this study have several policy implications. To facilitate the rapid diffusion of GM technology to farmers, both public and private sectors can play important roles. First, ability of seed companies to generate seed available in the market after commercial approval of a biotech crop affects the scale of initial adoption or numbers of farmers who can plant the new crop. Second, technology developers from either public research institutions or biotech companies are one of important facilitators in the initial diffusion of the biotech technology. Through field trials and demonstration, nearby farmers can learn the advantage of the technology and become the initial beneficiary, which will stimulate other farmers to follow them. Third, local technology extension service and training are also critical in disseminating appropriate information and knowledge to farmers so that they can fully benefit from the new technology. Fourth, engagement of local village leaders in arranging the purchases of biotech crop seed helps farmers, particular smallholders, to access the new technology. Last but not least, similar to other technology diffusion, social network affects the rapid adoption and pathways of Bt cotton diffusion.

Farmer Experience

The following are excerpts from the monograph Farmers First, an ISAAA publication in 2013 which is a compilation of testimonies from farmers who planted biotech crops in China, India and the Philippines. These testimonies were obtained during the 2012 study funded by Templeton Foundation on *Adoption and Uptake Pathways of Biotechnology Crops* in the three countries.

Wang Yuping of Zhangzhai, Nancheng, Xiajin, Shandong, China
I used to plant ordinary cotton but bollworm infestation was a problem. I even wanted to give up until I was introduced to Bt cotton through a seed technician. He said Bt cotton is a transgenic crop and it is resistant to pests. I then bought seeds from the Bureau of Agriculture and began to grow Bt cotton. I also get subsidy as I grow the said variety. Everyone in our village is already planting Bt cotton. The production of cotton is higher than the traditional variety by more than 50 percent. Bt cotton is really good. It is productive, it is profitable, and it saves labor and pesticide.

Kaibo Wang of Jiguan, Wangjiang, Anhui, China
I am a 57-year old farmer who is presently planting 15 mu (1 ha) of Bt cotton. I have been planting cotton for 40 years but I started to plant Bt cotton in 1999. By 2002, all cotton planted in my farm is already Bt. The crop was introduced to me by a relative. After trying Bt cotton, I learned that it did not

need much pesticide and that it had higher yield than its conventional counterpart. Adopting Bt cotton also resulted to less labor and thus it became easier for me to manage my farm. I also commend the good quality of Bt cotton which has better cotton fiber.

Li Yizheng of Qinahuozhuang, Xinshengdian, Xiajin, Shandong, China
I was introduced to Bt cotton when our county's cotton improvement office recommended the seed to us. When we planted Bt cotton, we saved on labor and had a more productive yield. Bt cotton reduces need for pesticide so we work less in the field, but earn more. To improve our Bt cotton farming, I and my fellow farmers share each other's methods on proper cultivation. I hope the government will continue to promote good varieties of cotton.

Chen Jianbin of Da Lisi, Wangkou, Xinji City, Hebei Province, China
We were introduced to Bt cotton when a seed company worker visited our village and distributed the seed variety. I tried it and found it good. My crop was not infested by pests so I continued to plant the variety. There is not much problem. Actually, there are lots of benefits. We save labor and time; the production is also high so our income increases too. Because of planting Bt cotton, we have built a big house, earned more money, and now we live a better life. Most of the cotton planted in our village is already Bt cotton. The ordinary cotton which is not pest-resistant has almost disappeared. We farmers always share our experiences in growing Bt cotton with each other and we apply the good practices we learned from our fellow farmers.

Xu Derong of Zhangzhai, Xiajin, Shandong, China
I started to plant Bt cotton in 1998. They initially introduced Bt cotton to young people since they are open-minded. People in our village did not want to grow Bt cotton, they did not believe it is resistant to pests. I could not believe it as well. At first, there were only 30 families who were growing Bt cotton. Then my uncle introduced Bt cotton in our village. On the first year, I planted a little. Since then, I began to expand my Bt cotton farm. Aside from my existing 0.13 ha cotton farm, I leased another mu (0.13 ha) for Bt cotton, and later on I expanded my Bt cotton farm to another 7-8 mu (0.47-0.54 ha). I think Bt cotton is better. With ordinary cotton we only got production of over 150 kg per 0.067 ha. Now we get 250-300 kg harvest per 0.067 ha. Before, we all thought that the input cost is too high. Seeds are expensive too. But those who didn't grow Bt cotton gained nothing after the harvest period. Now, people realize that planting Bt cotton can make more money.

Li Yihua of Qianhuozhuang, Xinshengdian, Xiajin, Shandong, China
I have been growing Bt cotton for eight years. Some people from the government's cotton improvement office brought the Bt cotton seeds to us. They wanted us to try the variety. That time, we could not believe that there is a kind of cotton that can resist pests. But we tried it and it turned out that Bt cotton can really resist pests. Bt cotton is also profitable. Gradually, people began shifting from ordinary cotton to Bt cotton. The production of Bt cotton proved to be high. Nearly all farmers in our village want to grow Bt cotton. At first there were only few people who wanted to grow Bt cotton. The next year, Bt cotton seeds were no longer enough in our village. In the third year, Bt cotton turned out to be the seed of choice.

Li Wenjing of Da Lisi, Wangkou, Xinji City of Hebei, China
Bt cotton was recommended to us by a Chinese agricultural company. The village council also persuaded

us to grow Bt cotton as they said that the variety has lots of benefits compared to the conventional cotton. Ever since I planted Bt cotton, it saved me labor and money as I do not buy pesticide. We gain higher income unlike when we were growing ordinary cotton. Bt cotton is productive and the pests are minimal. The cotton bollworms were hugely reduced too. Since we planted Bt cotton, we had higher family income. We renovated our house, bought a new tractor, and a colored TV as well. I already saw its benefits and potentials so I recommended it to my relatives and friends in other villages.

Ma Congbiao of Mazhuang Village, Xinji City, Hebei, China
We have been planting Bt cotton on a five mu (0.34 ha) farm for more than a decade. Our village leaders influenced us to plant Bt cotton by organizing a meeting to introduce the benefits of planting Bt cotton to farmers. Planting Bt cotton saves labor and time. Pests were also minimized thus the use of pesticides was reduced. Most of all, we increased our cotton production. Because of this, Bt cotton became very popular to farmers. We have acquired new appliances and furniture for our house. Compared with the past, our life has really improved. To further improve our Bt cotton cultivation, we farmers talk about our harvest and who grows Bt cotton better. We also share our knowledge and experiences on planting the crop.

PARAGUAY

Paraguay has successfully grown RR®soybean for ten years since 2004. In 2014, Paraguay grew a record hectarage of 3.9 million hectares of soybean, maize and cotton compared with 3.6 million in 2013, an 8% increase over 2013. Of the total biotech crop hectarage of 3.9 million hectares, 3.3 million were soybean (including up to ~170,000 of the stacked Bt/HT product), 500,000 hectares of biotech maize and ~36,000 hectares of biotech cotton. Provisional economic gains over the period 2004 to 2013 is estimated at US$924 million and the benefits for 2013 alone at US$96 million.

Paraguay is the world's number four exporter of soybeans. It grew biotech soybean unofficially for several years

PARAGUAY

Population: 6.6 million

GDP: US$23.8 billion

GDP per Capita: US$5,500

Agriculture as % GDP: 23.5%

Agricultural GDP: US$5.6 billion

% employed in agriculture: 26.5%

Arable Land (AL): 4.1 million hectares

Ratio of AL/Population*: 3.0

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

Commercialized Biotech Crop: HT Soybean

Total area under biotech crops and (%) increase in 2014:
3.9 Million Hectares (+8%)

Farm income gain from biotech, 2004-2013: US$0.92 billion

*Ratio: % global arable land / % global population before it approved four herbicide tolerant soybean varieties in 2004. In 2014, Paraguay was expected to grow a total of 3.4 million hectares of soybean, of which a record 3.3 million hectares (approximately 95% adoption) was biotech herbicide tolerant soybean. This increase in 2014 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.

Three biotech maize events and one biotech soybean were officially approved in 2014 (Table 22). By 2014, Paraguay was expected to grow a total of approximately 1.0 million hectares of maize of which 50% 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 for many years. In October 2011, Paraguay approved Bt cotton for commercial production. Paraguay was expected to grow 45,000 hectares of cotton in 2014, of which 80% were biotech. Intacta™, a new stacked HT/IR soybean was authorized and launched in 2013 and grown on ~170,000 hectares in 2014. 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 provisionally estimated to have enhanced farm income from biotech soybean by US$924 million in the period 2004 to 2013 and the benefits for 2013 alone is estimated at US$96 million (Brookes and Barfoot, 2015, Forthcoming).

Table 22. Commercial Approvals for Planting in Paraguay (2004 to 2014)

Crop	Trait	Event	Year
Soybean	Herbicide tolerance (HT)	40-3-2	2004
	HT x IR	MON 87701 x MON89788	2013
	HT	CV127	2014
Cotton	Insect tolerance (IR)	MON 531	2011
	IR x HT	MON 531 x MON 1445	2012
	HT	MON 1445	2012
Maize	IR	MON 810	2012
	IR	BT11	2012
	IR, HT	TC1507	2012
	IR x HT	MON 89034 x MON 88017	2012
	HT	NK603	2014
	IR	MIR 162	2014
	IR x HT	MON 89034 x TC1507 x NK603	2014

Source: G. Levitus (Personal Communication), 2014.

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 in the region.
- Instruct CAS to continue its coordination, harmonization and promotional efforts on activities related to GMOs.

PAKISTAN

2014 was the fifth year of cultivation of insect resistant Bt cotton varieties and hybrids in Pakistan. In 2014, Pakistan achieved a near optimal adoption of Bt cotton cultivation at 88% or 2.85 million hectares out of a total of 3.2 million hectares of cotton, and a 4% growth over 2013. Approximately 700,000 smallholder cotton farmers planted and benefited from Bt cotton in 2014. It is noteworthy that Bt cotton occupied almost the entire cotton crop hectarage in the Punjab and Sindh provinces of Pakistan. Around 30 open pollinated Bt cotton varieties and 2 hybrids of Bt cotton were approved for planting in four intensive cotton growing provinces of Pakistan during 2010 to 2014. The Pakistan Central Cotton Committee (PCCC) of the Ministry of Textile Industry, which was relocated to the Central Cotton Research Institute (CCRI), Multan, estimated cotton production at 15 million bales in the 2014-15 Kharif season.

Pakistan has suffered an enormous opportunity cost in not taking full advantage of Bt cotton technology in the absence of a comprehensive policy on cotton and textile sector and uncertainty surrounding biosafety regulation in the country. Pakistan achieved a cotton production of almost 15 million bales in 2014-15, however Pakistan missed the target of 19.1 million bales as projected in the "National Cotton Vision 2015" in 2010. As a result of the cotton demand-supply gap and the power crisis, the export of textiles, predominantly cotton textile, registered a sharp decline in 2014-15, and this will make it difficult to achieve the targeted US$15 billion textile export market.

In order to achieve its cotton and textile targets, Pakistan probably needs to take policy decisions at two levels. First, the country has to resolve the inconsistency of the post 18th Amendment of the Constitution and reinstate the functioning of the National Biosafety Committee (NBC) of the Pakistan Environmental Protection Agency (Pak EPA) of the Ministry of Climate Change (MOCC). Second, the Ministry of Textile Industry (MOTI) needs to specify and implement the Textile Policy 2014-19 to overcome the multiple constraints faced by the textile sector in the country. The cost/time effective functioning of the NBC is a must in order to undertake a rigorous and scientific assessment to expedite biosafety clearance and commercialization of pending applications of GM crops; this includes the double gene Bt cotton, stacked trait for insect and herbicide tolerant cotton, and stacked GM Bt/HT maize. The NBC at the federal level needs to regularize the existing Bt cotton varieties which were already approved by the Punjab Seed Council (PSC) in order to optimize the potential of GM technology in Pakistan. Nevertheless, it is estimated provisionally that the economic gains from existing Bt cotton varieties for Pakistan for the period 2010 to 2013 was US$1,615 million and US$368 million for 2013 alone.

PAKISTAN

Population: 176.7 million

GDP: US$210 billion

GDP per Capita: US$1,190

Agriculture as % GDP: 22%

Agricultural GDP: US$37.2 billion

% employed in agriculture: 45%

Arable Land (AL): 21.5 million hectares

Ratio of AL/Population*: 0.5

Major crops:
- Cotton
- Wheat
- Sugarcane
- Rice
- Maize

Commercialized Biotech Crop: Bt Cotton

Total area under biotech crops and (%) increase in 2014:
2.9 Million Hectares (+4%)

Farm income gain from biotech, 2010-2013: US$1,615 million

*Ratio: % global arable land / % global population

Effective Functioning of Biosafety Regulatory System

In April 2010, the federal Government of Pakistan enacted the 18th Amendment pursuant to the Constitution (18th Amendment) Act, 2010 which devolved many federal subjects including environment to the Provinces. The 18th Constitution Amendment effected a major change in the administration of various ministries at Federal and Provincial levels. Of the four ministries relevant to agricultural biotechnology, three of them including the Ministry of Food and Agriculture (MINFA), Ministry of Environment (MOE) and Ministry of Health (MOH) were devolved to the provincial Government on 30th June 2011. Despite this, some relevant functions enlisted in federal legislative on agriculture, environment, health and S&T were retained at the federal level by creation of new ministries to look into special areas of agriculture under the Ministry of National Food Security and Research (MNFS&R) and matters of environment under the Ministry of Climate Change (MOCC) (MNFS&R, 2012 and MOCC, 2012). The Pakistan Environment Protection Act (Pak EPA) administers the Pakistan Environment Protection Act, 1997 shifted to the Ministry of Climate Change (MOCC) in 2012. Thereafter, matters pertaining to the regulation of GM crops and biosafety were transferred and the National Biosafety Centre (NBC) was shifted to the Pak EPA at federal level contrary to the devolution of matters of environment by establishing new ministry of environment at the respective provinces (MLJ&HR, 2013).

In March 2014, the National Biosafety Committee (NBC) met for the first time in 2014 and approved 15 Bt cotton varieties at federal level, which were commercialized by the Punjab Seed Council (PSC) between 2010 and 2013. However, the statutory authority of NBC was challenged in the Lahore high court in the wake of the 18th Amendment of the Constitution and NBC remained dysfunctional in the absence of clarity during the rest of the year (Dawn, 2014). Meanwhile, on 30th June 2014, the contract of the National Biosafety Centre (NBC) had expired and not renewed resulting in the laying off of the technical and administrative staffs. Currently, NBC is attempting to function without any permanent staff and the EPA officials are temporarily looking after the affairs of NBC with a very limited technical capacity to handle cases related to field trials and commercial approval of GM crops. There is a strong need of a functioning regulatory agency at the federal or provincial level which can decide on multiple GM crops and biotech related applications. It is estimated that 100 applications are pending with the Government of Pakistan. For the Technical Advisory Council (TAC) and the National Biosafety Committee (NBC) to be operational, the Government of Pakistan needs to reinstate the biosafety and GM crops clearance at federal level by issuing a new Ordinance by the President or to table the Pakistan Biosafety Act to be passed by the Parliament of Pakistan (Khursid, 2014). This will also help the country avert confusion at the international level in order to comply with the global obligations under the Cartagena Protocol on Biosafety (CPB) of which Pakistan is a party since 31 May 2009.

Legislating the Seed (Amendment) Act 2014

With the renewed mandate at federal level, the Ministry of National Food Security and Research (MNFS&R) embarks on a much needed path to consolidate the legislations related to agriculture, to coordinate programs with respective provinces, to establish the National Food Security Council, to announce the "National Food and Nutrition Security Policy" and to unveil the first "National Zero Hunger Action Plan". Two important legislations including "the Seed (Amendment) Bill, 2010" and "Plant Breeder's Rights Bill, 2010" are on the top priority of the federal food security ministry to give an impetus to the seed sector in the country (MNFS&R, 2012). In August 2014, MNFS&R introduced the much awaited Seed (Amendment) Act 2014 in the National Assembly of Pakistan to amend the Seed Act 1976 (XXIX of 1976). The Federal Ministry of National Food Security and Research (MNFS&R) introduced the Amended Seed Act 2014 in the National Assembly of Pakistan based on the resolution passed by the respective provinces authorizing the federal Government to bring suitable changes in agriculture and seed policy (NA, 2014). The Amended Seed Act 2014 upon enactment by the National Assembly of Pakistan shall effect changes in the Seed Act 1976. The Amended Seed Act 104 aims at fulfilling the requirement of modern seed industries and will give impetus to the development, certification, registration and commercialization of improved open pollinated varietal and hybrid seeds in Pakistan. The main objectives of the Amended Seed Act 2014 include:

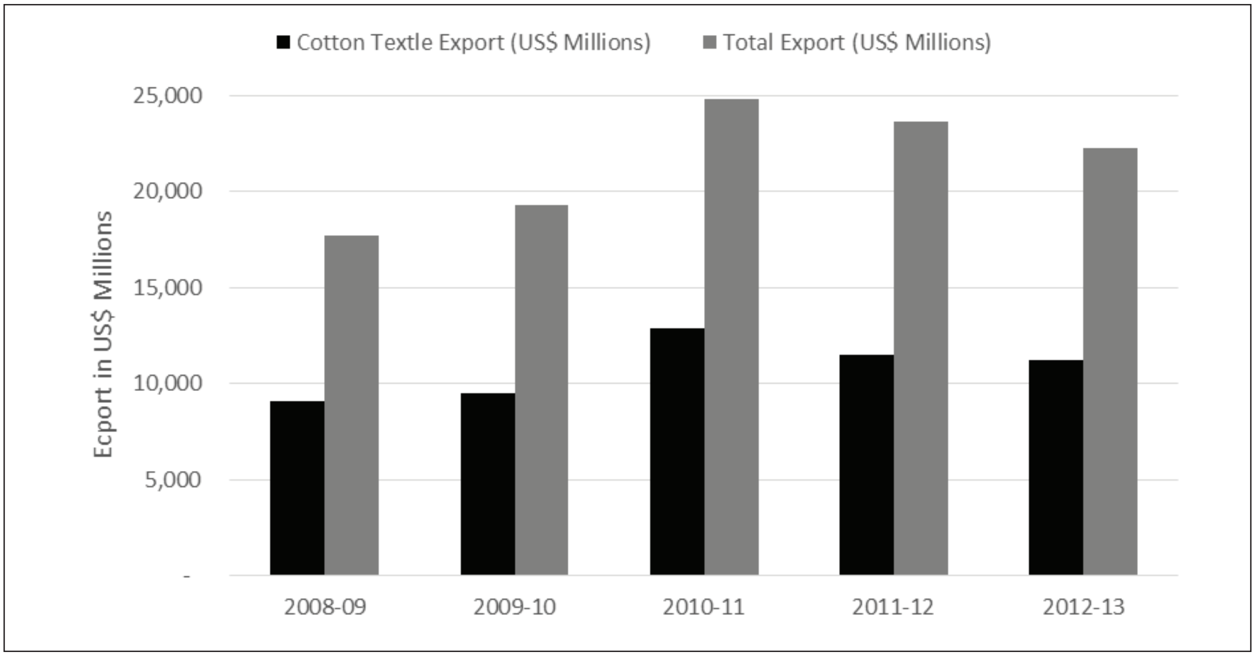
- Delineation on the role of registered seed companies, seed dealers, processing units and fruit plant nurseries established in public or private sector
- Allow public or private sector to produce basic seed for its multiplication and certification
- Allow public or private sector to establish accredited seed testing laboratories
- Allow registration of GM crops subject to undertaking by applicant that no terminator technology is involved in the development of seed variety. A certificate from NBC would be pre-requisite for approval of plant variety.
- Penalize for any violation and the penalties have been increased to meet the latest monetary trends with the objective of being effective deterrence against sale of substandard seed in the market (NA, 2014).

With the enactment of the Amended Seed Act 2014, the country expects to control the sale of substandard and misbranded seeds, improve quality of seeds, enhance the participation of public and private sector and increase private sector investment in seed and agriculture sector to achieve the food security objectives. In the past, the food security ministry has laid an emphasis by drafting the National Food and Nutrition Security Policy to be announced in the future (The Nation, 2013). The policy intends to reduce the current food insecurity situation by 50% by 2030 and to bring down the poverty and food insecurity to zero level by 2050 (Daily Times, 2012). In this connection, the minister of national food security and research reiterated the role of seed and biotechnology in agriculture and stated that *"biotechnology is a modern tool to improve productivity of agriculture sector, and application of its benefits at farmers' doorstep would play an important role in enhancing productivity that ultimately will help to ensure food security and reducing poverty in the country"* (MNFS&R, 2013a). In 2014, the President of Pakistan Mr. Mamnoon Hussain reiterates the country's commitment to finalize and implement the National Food and Nutrition Security Policy focusing on four main policy features; sustainable food availability, food accessibility, food utilization, nutrition and stability in food supplies with vision of healthy and active life. ***"Pakistan's Government attaches high priority to agriculture sector and connected research agenda. There is great need for investment in agriculture sector to ensure food security and poverty alleviation in Pakistan"*** said President Mr. Mamnoon Hussain while addressing the occasion commemorating 50 years of Pakistan-US Cooperation in Agriculture and Celebrating Dr. Norman Borlaug's 100th Birthday (PARC, 2014).

Twin Challenges of Cotton and Textile Sector

Cotton and textile sectors are the backbone of economy and employment in Pakistan. The sector employs about 40% of total labor force and earns approximately US$15 billion or roughly half of the total export from the country. It contributes around 10% of the national gross domestic products (GDP). Raw cotton, yarn and cloth form a major portion of textile export from Pakistan. It is estimated that cotton based textiles constitute two third of total textile production and export from Pakistan. The availability of raw cotton played a key role in the growth and expansion of cotton textile industry in Pakistan. Figure 20 shows the export of cotton textile vis-à-vis total export from Pakistan from 2008 to 2013. In the recent years, the export of textile from Pakistan has shown a downward trend due to demand supply constraints of raw cotton and limited supply of power and gas to textile industry in the Punjab province of Pakistan.

Figure 20. Export of Cotton Textile vis-à-vis Total Export from Pakistan, 2008 to 2013

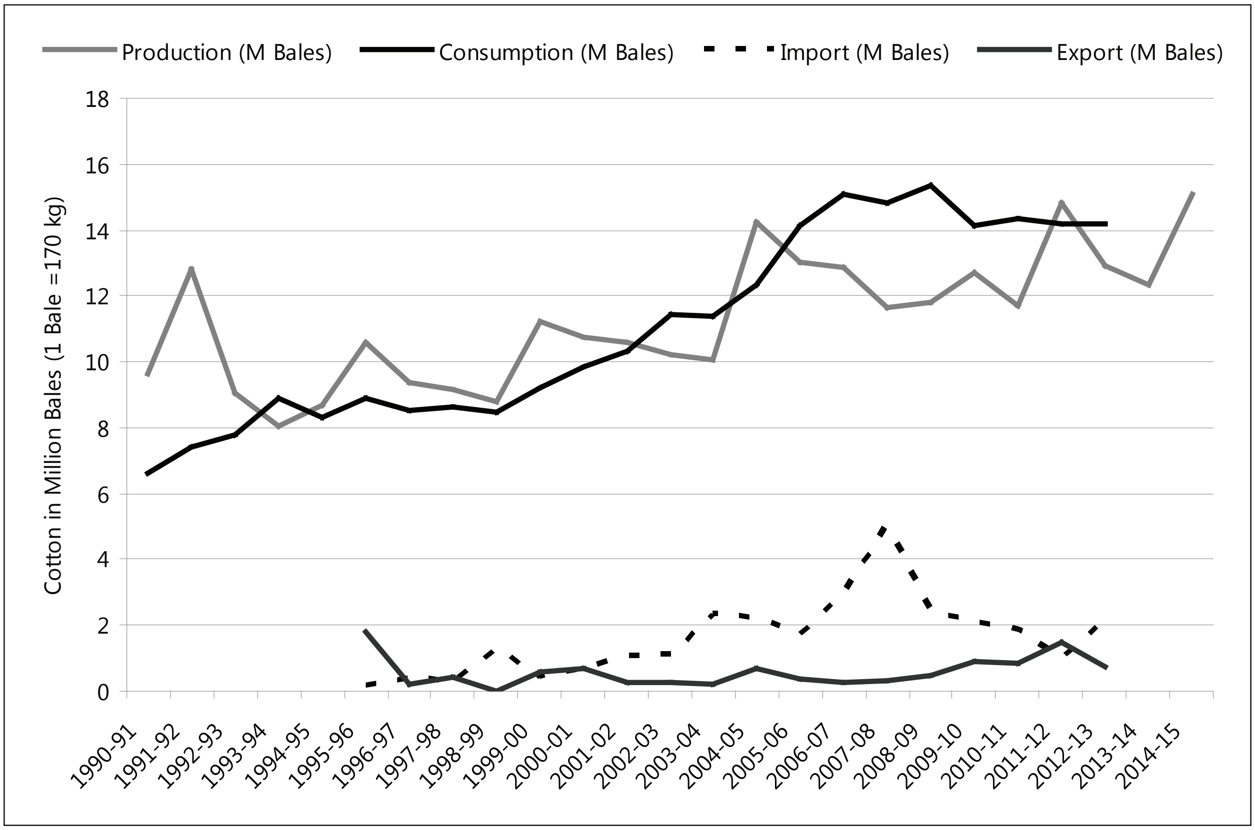


Source: PCCC, 2014; Analyzed and compiled by ISAAA, 2014

Despite the introduction of Bt cotton in 2010, Pakistan hardly produces raw cotton of 15 million bales in 2014-15. Pakistan produces roughly 12-14 million bales of cotton annually. There are up to 800,000 cotton farmers in the country (an average holding size of 4 hectares) growing over 3.2 million hectares of cotton mainly in Punjab, Sindh, Balochistan and Khyber Pakhtunkhwa provinces. A large number of farm families and laborers depend on cotton crop for their income and livelihood. Punjab alone occupies almost 80% of total cotton in Pakistan with the balance of cotton hectarage in the Sindh with less in Balochistan and Khyber Pakhtunkhwa (KP). ISAAA Brief 43, 44 and 46 (James, 2011; 2012 and 2013) provide 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.

In Pakistan, the area under cotton has not increased substantially over the last two decades from 2.7 million hectares in 1990-91 to 3.2 million hectares in 2014-15. During the same period, cotton yields remained almost stagnant at 550 kg to 750 kg of lint per hectare (Figure 21). Annual cotton production stalled between 12 to 14 million bales whereas demand for cotton doubled from 6.6 million bales in 1990-91 to 13.59 million bales in 2011-12. In the past, the country witnessed a dismal growth in cotton production, which remained below 10 million bales from 1995 to 1999 and around 12 million bales from 2000 to 2011 before touching the high level of 13.59 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

Figure 21. Cotton Production, Consumption, Export and Import in Pakistan, 1990 to 2014



Source: PCCC, 2014; Analyzed and compiled by ISAAA, 2014

provinces (Hussain & Awan, 2011; PCGA, 2012). Figure 21 shows cotton production, consumption, export and import in Pakistan from 1990 to 2014.

Moreover, the current cotton production level is much lower than the domestic cotton requirement by the textile industry. In recent years, the export of raw cotton has declined and the import of cotton has shown an upward movement (Figure 21). This is a serious cause of concern for the cotton and textile sector in the country. 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 Khyber Pakhtunkhwa, 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 mark of 13.59 million bales and it would be noteworthy for the country to achieve the benchmark of

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. As early as 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.

However, Pakistan suffered an enormous opportunity cost in not taking full advantage of Bt cotton technology in the absence of a comprehensive policy on cotton and textile sector and uncertainty surrounding the biosafety regulation in the country. Pakistan hardly achieved the target cotton production of 15 million bales in 2014-15 far below than estimated 19.1 million bales as envisioned in the "National Cotton Vision 2015" (PCCC, 2011). As a result of the cotton demand-supply gap and power crisis, the export of textiles, predominantly cotton textile, registered a sharp decline and will severely hamper the potential US$15 billion textile export market in 2014-15 (Tribune, 2014 and Daily Times, 2014).

In the fifth year of commercialization of Bt cotton in 2014-15, the Cotton Crop Assessment Committee (CCAC) of the Ministry of Textile has estimated cotton production of 15 million bales (AFP, 2014; MOTIa, 2014; GAIN, 2014). The regulatory system in Pakistan is reeling under the uncertainty of timely approval of additional Bt cotton varieties and approval of the second generation Bt cotton events like BG-II and BG-II RRF cotton that marred the country's prospects to surpass the benchmark target of 15 million bales by 2015 (Business Recorder, 2013a). With the looming deficit in cotton production in the recent years, the country has to import around 3 million bales of raw cotton to meet the demand of textile industry (Business Recorder, 2013b) (Ministry of Textile Industry, 2012; PCGA, 2012; Business Recorder, 2012b).

In order to achieve the cotton and textile targets, Pakistan needs to take policy decisions at two levels; first the country has to resolve the inconsistency post 18th Amendment of the Constitution and reinstate the functioning of the National Biosafety Committee (NBC) of the Pakistan Environmental Protection Agency (Pak EPA) of the Ministry of Climate Change (MOCC). Second, the Ministry of Textile Industry needs to announce and implement the Textile Policy 2014-19 to overcome multiple constraints faced by the textile sector in the country (MOTI, 2014b). The cost/time effective functioning of NBC is a must to undertake rigorous and scientific assessment and biosafety clearance and commercialization of pending applications of GM crops including double gene Bt cotton, stacked traits insect and herbicide tolerant cotton and stacked GM corn. NBC at the federal level needs to regularize the existing Bt cotton varieties which were approved by the Punjab Seed Council (PSC) to effectively harness the potential of GM technology in Pakistan (The Nation, 2014).

Adoption of Bt Cotton in Pakistan, 2010 to 2014

In 2010, Pakistan officially allowed the commercial cultivation of Bt cotton and joined the group of major

Bt cotton growing countries including the USA, China, India, Australia, South Africa, Brazil, Argentina, Columbia, Mexico, Costa Rica, Myanmar and Burkina Faso. These countries contribute a very large proportion of global cotton production and trade. This official approval was spurred by the demand for genuine good quality Bt cotton in the country with the following specifications: resistant to cotton leaf curl virus (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). In the fifth year of commercialization, 2014, Bt cotton was planted by ~700,000 farmers on 2.85 million hectares, occupying a substantial 88% of the total 3.2 million hectares of cotton area planted in Pakistan; this compares with 2.8 million hectares of Bt cotton in 2013 and 2012, 2.6 million hectares of Bt cotton in 2011, equivalent to 81% of the 3.2 million hectares cotton area planted nationally (Table 23). Therefore, in 2014, Pakistan planted 2.85 million hectares of biotech cotton which is over 10% of total biotech cotton area of the world.

On 31 March 2010, for the first time, the Punjab Seed Council (PSC) under the Ministry of Agriculture of the Punjab province decided to officially approve the commercial cultivation of 8 insect resistant Bt cotton varieties and one Bt cotton hybrid. Subsequently, the former 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. Thus, 8 cotton varieties expressing MON531 and one hybrid expressing the fusion gene *cry1Ac* and *cry1Ab* in GFM event received approval for commercial cultivation in 2010 (Punjab Seed Council, 2010; NBC, 2010). In 2011, PSC conditionally approved the renewal of four Bt cotton varieties IR-1524, FH-113, Ali Akbar-802 and Neelam-121, which were conditionally approved in 2010 for one year, pending improvement of fiber characteristics (Pakistan Today, 2011).

In February 2012, 8 new Bt cotton varieties were approved including unconditional approval of four new insect resistant Bt cotton varieties FH-114, CIM-598, SITARA-009 and A-ONE; and one year conditional approval for four additional Bt cotton varieties TARZAN-1, NS-141, IR-NIBGE-3 and MNH-886. In addition, three insect resistant Bt cotton varieties including IR-1524, ALI AKBAR-802 and NEELAM-121 which received one year conditional approval in 2011 were approved, but FH-113 was discontinued. Therefore, in 2012, small cotton farmers in Pakistan had 16 Bt cotton varieties for commercial cultivation in three intensive cotton growing provinces of Punjab, Sindh and Balochistan.

In 2013, PSC approved additional 15 Bt cotton varieties and permission for renewal of 8 provisionally approved Bt cotton varieties expiring in 2013 in the absence of the environmental and biosafety clearance from the federal National Biosafety Committee (NBC) of the Pakistan Environmental

Table 23. Adoption of Bt Cotton in Pakistan, 2010 to 2014

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%
2013 - 14	2.8	3.2	86%
2014 - 15	2.85	3.2	88%

Source: Analyzed and compiled by ISAAA, 2014.

Protection Agency (Pak EPA), Ministry of Climate Change (MOCC). Hence, all the approved 15 Bt cotton varieties including 8 varieties which were provisionally approved in 2012 were also awaiting formal environmental and biosafety clearance and commercialization license from NBC (PSC, 2013) (Appendix 6). In spite of the delay in the formal commercialization by the federal NBC, the public and private sector institutions have made available in 2013, seeds of the 30 Bt cotton varieties and 2 hybrids provisionally approved by the PSC between 2010 and 2013 in the three intensive cotton growing provinces of Punjab, Sindh and Balochistan in Pakistan. The regulatory uncertainty caused by NBC led to delay in approval of additional Bt cotton varieties and deregulation of event based approval system of Bt cotton as recommended by the Expert Sub Committee (ESC) of the Punjab Seed Council (PSC), Punjab province, Pakistan (Appendix 6). In 2014, the NBC at the federal level endorsed the approval of 15 Bt cotton varieties which were approved for commercial cultivation by PSC from 2010 to 2013 (Business Recorder, 2014). In addition, there were 8 new Bt cotton varieties for field tested in 2014 and will be considered for commercial approval by the Punjab Seed Council (PSC) in 2015.

Appendix 6 shows the summary of commercial release of 30 different Bt cotton varieties and 2 Bt cotton hybrids in Pakistan between 2010 and 2014. Out of the approved 32 Bt cotton varieties, almost half were developed by the private sector seed companies and remaining half were developed by public sector research institutes of Federal and Provincial Government in Pakistan including Cotton Research Station, Central Cotton Research Institute, Nuclear Institute for Agricultural Biology, Islamia University and Punjab University respectively. 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). Almost all approved Bt cotton varieties contains the *cry1Ac* gene (MON531 event) which have been developed by public and private sector institutes, whereas the one Bt cotton hybrid GN-2085 expressing fusion gene *cry1Ac* and *cry1A*, has been developed by a local private seed company. Importantly, each Bt cotton variety approved by PSC has to be cleared for biosafety and commercialization by the federal NBC for the variety to be registered by the Federal Seed Certification and Registration Department (FSC&RD) before being sold to farmers in the country.

Prospects of GM Crops in Pakistan

In the early 1970s, Pakistan was the first country to adopt and popularize the semi-dwarf high yielding wheat varieties that subsequently facilitated the implementation of the Green Revolution in Pakistan. Over the years, Pakistan has developed a well established infrastructure and R&D programs for crop improvement particularly in major crops like wheat, cotton, rice, maize and sugarcane, both at the federal and provincial levels. In recent years, the Pakistan Atomic Energy Centre (PAEC) and the Pakistan Agricultural Research Council (PARC) have invested US$17 million by establishing four biotech institutes namely: National Institute for Biotechnology and Genetic Engineering (NIBGE), Faisalabad; Centre of Excellence in Molecular Biology (CEMB), Lahore; National Institute of Genomics and Advanced Biotechnology (NIGAB), Islamabad; and Agricultural Biotechnology Research Institute (ABRI), Faisalabad. The crops under genetic transformation by different public sector institutions include wheat, rice, sugarcane, cotton, soybean, chickpea, groundnut, brassica, potato, tomato and chili. In addition, 26 centres at various agricultural crop institutes and universities have been modernized to undertake tissue culture related activities, crop improvement using marker-assisted selection techniques, DNA testing and GMO detection in Pakistan. In addition, large numbers of domestic and multinational seed companies are undertaking R&D of various crops using genetic modification technologies.

These companies include Four Brother seeds, Ali Akbar Seeds, Neelum seeds, Weal-AG Corporation, Guard Agriculture Research Services, Monsanto, DuPont/Pioneer, Syngenta and Bayer Crop Science in Pakistan.

In recent years, the National Biosafety Committee (NBC) approved the large scale field trials of various events of cotton including stacked traits of insect resistance and herbicide tolerance cotton and maize in the country. Notably, between 2010 and 2013 there were approvals of second year large scale field trials of BGII cotton, BGIIRRF cotton and Bt/HT maize. Maize is a major feed crop in Pakistan grown on over 1 million hectares, and it is possible that Pakistan may approve the commercial cultivation of biotech maize in the near future to help maize farmers to substantially improve their maize yield and its competitiveness in the international maize market. Three different events of stacked insect resistant and herbicide tolerant maize of Monsanto, Pioneer and Syngenta were extensively field tested between 2010 and 2013 and are nearing the commercial approval in Pakistan (Table 24). Biotech maize, Bt/HT maize has achieved a considerable progress in the Philippines, and Vietnam and other Asian countries including India, China and Indonesia are actively field testing to assess biosafety and agronomic advantage of biotech maize.

It is estimated that with the official release of first generation insect resistant cotton varieties and hybrids in 2010, along with expected release of stacked traits of biotech cotton before 2015, Pakistan could accrue significant benefits of approximately US$800 million per year to its farm economy, assuming a 90% adoption of biotech cotton (Industry Estimates, 2010). Additionally, it is expected that a widespread adoption of biotech cotton would substantially reduce insecticide sprays, less exposure of farmers and farm laborers to insecticides, higher quality of cotton and higher return to cotton farmers and overall gains to the farm economy at national level.

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 being planted then, 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 Punjab Seed Corporation (PSB) officially approved 8 Bt cotton varieties and one hybrid containing event MON531 and GFM event. In 2014, around 30 Bt cotton varieties and 2 Bt cotton hybrids were available for planting across the major cotton growing area. In the last five years, Pakistan increased adoption of Bt cotton from 2.4 million hectares in 2010 to 2.85 million hectares in 2014.

Nazli et al. (2012) published a study 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)."***

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

Table 24. The Status of Field-trial of GM Crops in Pakistan, 2010-2014

No.	Crop	Gene	Event	Developer	Remarks
1.	Cotton	*cry1Ac* and *cry2A*	–	CEMB & Ali Akbar	Field trial conducted
2.	Cotton	*cry1Ac* and *cry2Ab*	MON15985	Monsanto	Import permit granted, No trials yet
3.	Cotton	*cp4 epsps* gene	MON 88913	Monsanto	Import permit granted, No trials yet
4.	Cotton	*cry1Ac, cry2Ab* and *cp4epsps*	MON15985 × MON88913	Monsanto	Import permit granted, No trials yet
5.	Maize	cp4epsps	NK603	Monsanto	Advance field trials conducted
6.	Maize	*cry2Ab2* & *cry1A.105* and *CP4EPSPS*	MON89034 × NK603	Monsanto	Advanced field trials conducted
7.	Maize	*cry1F, cry1Ab* and *CP4EPSPS*	TG1507 × MON810 × NK603	Pioneer	Advanced field trials conducted
8.	Maize	*cry1Ab* x *mESPSPS*	Bt11 × GA21	Syngenta	Field trials conducted
9.	Sugarcane	–	–	NIBGE	Field trials conducted
10.	Wheat	*DREB1A* and *HVA1*	–	NIBGE	Field trials conducted

Source: Analyzed and Compiled by ISAAA, 2014.

chemical pesticide use, higher yields, and higher gross margins, consistent with 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, stacked trait Bt cotton which has been field tested in 2010 to 2013 offer Pakistan new opportunities for boosting cotton yields which have been almost stagnant for the last two decades.

It is provisionally estimated that the economic gains from biotech crops for Pakistan for the period 2010 to 2013 was US$1.6 billion and US$368 million for 2013 alone (Brookes and Barfoot, 2015, Forthcoming).

SOUTH AFRICA

In 2013, severe potential impact of early drought was offset by widespread rains in mid-summer, resulting in a record maize crop of 14.3 million MT. This was attained because of improved yield potential of superior genetics combined with biotech traits. Summer crop areas in South Africa were again in the grip of a serious drought in 2014, which has delayed onset of planting. The general expectation is a decline in maize planting, the dominant biotech crop, to reach 2.5 million hectares, down from 2.9 million in 2013, a modest 7% reduction. Some farmers also have difficulty in getting crop insurance without which, crop financing is constrained.

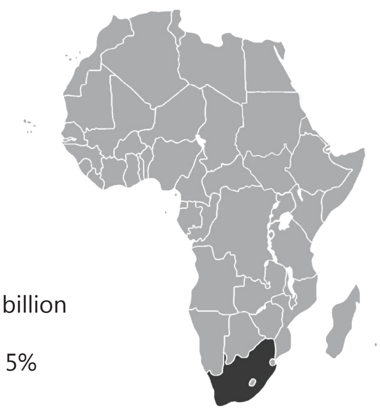
The estimated total biotech crop area for maize, soybean and cotton in 2014 is estimated at 2.7 million hectares, compared with 2.9 million hectares in 2013, a decline of 7%. Biotech maize hectarage is 2.15 million in 2014 compared with 2.4 in 2013. Soybeans are a proven beneficial crop for rotation, conservation agriculture and soil health, and planting continues to increase. The total area planted to soybeans is estimated to increase from 520,000 hectares in 2013 to 600,000 in 2014, with an adoption rate of 92%, to give 552,000 hectares herbicide tolerant soya. Total cotton area is expected to increase marginally to 9,000 hectares (8,000 hectares in 2013). Biotech cotton adoption rate remained at 100%, of which ~95% are IR/IR/HT stacked; single trait herbicide tolerant cotton is used only as a mandatory refuge for stacked gene biotech cotton fields.

It is estimated that a total of 2.5 million commercial hectares of maize will be planted in 2014, 58% white and 42% yellow, down from 2.7 in 2013. Of the total maize area, 86% or 2.14 million hectares will be biotech; 83% of total white maize is biotech and 90% for total yellow maize. Of the 2.14 million hectares of biotech maize, 28% or 0.60 million hectares were insect resistant of which 20% is estimated to be the single Bt insect resistance gene and 80% two stacked Bt genes, 19% or 0.41 million hectares herbicide tolerant, and 53% or 1.13 million hectares stacked insect resistance and herbicide tolerance genes. The white maize crop of 1.247 million hectares comprised 83% biotech or 1.04 million hectares with the single Bt gene accounting for 30% or 0.31 million hectares, herbicide tolerance for 13% or 0.14 hectares and IR/HT stacks at 57% or 0.59 million hectares. The yellow maize area of 0.90 million hectares will be 90% biotech or 0.81 million hectares; the biotech share represented by 25.7% insect resistance or 0.21 million hectares, 25.5% or 0.20 million hectares herbicide tolerance and 48.8% or 0.40 million hectares stacked insect resistance-herbicide tolerance.

Three trends emerged from these data: first, that adoption of biotech is fairly similar for white and yellow maize with some differences due to region; second, that adoption of traits (insect resistance, herbicide tolerance and stacked for both) is almost 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 at grain silos (elevators) tested are positive for GM traits, pure GM or co-mingled. Some traders import or contract farmers for non-GM grain for certain customers. Thus, GM maize adoption has stabilized around 84-86%.

Total soybean plantings are estimated to have grown from 520,000 hectares in 2013 to 600,000 hectares in 2014. HT soybean is estimated at 552,000 hectares or 92% of the total area planted.

SOUTH AFRICA



Population: 50.5 million

GDP: US$408 billion

GDP per Capita: US$8,070

Agriculture as % GDP: 2%

Agricultural GDP: US$8.16 billion

% employed in agriculture: 5%

Arable Land (AL): 12.2 million hectares

Ratio of AL/Population*: 1.4

Major crops:
- Sugarcane
- Maize
- Wheat
- Grapes
- Potato

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

Total area under biotech crops and (%) increase in 2014:
2.7 Million Hectares (-7%)

Farm income gain from biotech, 1998-2013: US$1,553 million

*Ratio: % global arable land / % global population

Cotton production has continued to decline in recent years but Cotton SA expects a slight turn-around this year. Area to be planted in 2014 is expected to increase marginally to 9,000 hectares. All of the cotton is expected to be biotech with 95% stacked (Bt/Bt/HT) and 5% HT used for refugia.

The comprehensive GMO regulatory framework is based on a permit system of which there are some 12 types, apart from compulsory registration of facilities where GMOs are handled. There were 220 GMO permits granted from 1 January to 31 July 2014 of which maize accounted for 91.3%%, cotton 6.0% and soybeans for 2.7%. There were no new permits granted for GM vaccines. Maize seed import permits for 2014 (to 31 July) for commercial planting covered 5 permits for 579 MT and 7 seed export permits for 3,950 MT, apart from many small seed samples for testing, breeding, or multiplication. South Africa has shifted its commodity GM maize grain exports to new markets in Europe, Latin America, Asia and some African states. Commodity maize export permits granted up to July numbered 48 for over 2 million MT of maize grain. Approval has been given for maize trial release (contained field trials) for PhP34378, PhP36827, Bt11xTC1507xGA21, and Bt11xMIR162xTC507xGA21.

There were no new applications for GM sugarcane trials but some of the previous trials may still be on the field as ratoon crops. Import of commodity grains containing events not yet approved and registered in South Africa requires approval of permits for commodity clearance to comply with the Cartagena Protocol on Biosafety for trans-boundary movement of LMOs. Permit approvals in 2014 included soybean SHYTOH2 and maize MIR162, Bt11xMIR162xMIR604, TC1507x5307xGA21, Bt11xMIR162x5307xGA21, and MON89034xMON88017. Such commodity clearances will remain a common feature as grain exporting countries continue to approve many more new events than South Africa does.

It is noteworthy that this information is based on permits granted for contained 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 at all, and a GM event may be dropped after testing and may not be applied for commercial release. Only event identifiers are indicated, company details not shown.

No home-grown biotech crop innovations have as yet entered the national market, partly due to cost of regulatory approval. These include novel promoters, drought tolerance genes, maize streak virus resistance, and a range of experimental GM sugarcane events. The unique GM yeast for wine fermentation, MALO 1 has been registered for use offshore, but not in South Africa. New and updated policies and legislation are expected to add both new complexities and new opportunities for biotech crops. Mandatory labeling of "goods" containing GM/GMO ingredients or components, as prescribed in Regulation 7 of the Trade & Industry 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. Apart from an open workshop with affected parties held in September, there is no final text as yet to clarify the concerns raised. Part of the problem has been lack of stakeholder consensus approach or a common acceptable wording of the sub-regulations by industry members. The fact is that, by extending labelling requirements to import 'goods' with GM ingredients/components, these provisions have entered the domain of the WTO.

The national Bio-Economy Strategy will now move forward with drafting of an implementation process intended to reach the objectives of coordinating activities, develop new crop plants and animals, commercial competitiveness of plants and animals, bio-innovation, and enabling capabilities. Another major focus is the new national policy on food and nutrition security to address rural poverty and malnutrition. One element is the establishment of Centers of Excellence comprising a consortium of academic institutions and the Agricultural Research Council, with the private sector to become a partner. The Department of Science & Technology and the National Research Foundation have committed funding for these initiatives.

The several incidences of African maize stalk borer tolerance/resistance to Bt bio-toxin continue to be 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. To date no break-down in resistance to stacked Bt genes has been encountered. 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.

Economic Benefits

It is provisionally estimated that the economic gains from biotech crops for South Africa for the period 1998 to 2013 was US$1.6 billion and US$313 million for 2013 alone (Brookes and Barfoot, 2015, Forthcoming).

URUGUAY

Uruguay increased its biotech plantings of soybean and maize to 1.64 million hectares in 2014, an increase of over 7% from 1.47 million hectares in 2013. Herbicide tolerant soybean occupies 100% of the national soybean hectarage at ~1.55 million hectares. Biotech maize occupied 90,000 hectares in 2014, compared with 140,000 hectares in 2013. Of the 90,000 hectares of biotech maize, ~80% was the stacked Bt/HT product. 2014 was the 11th year for Uruguay to plant biotech maize. Provisionally, Uruguay has enhanced farm income from biotech soybean and maize of US$147 million in the period 2000 to 2013 and for 2013 alone at US$25 million.

URUGUAY

Population: 3.4 million

GDP: US$46.7 billion

GDP per Capita: US$15,080

Agriculture as % GDP: 8.2%

Agricultural GDP: US$3.8 billion

% employed in agriculture: 13%

Arable Land (AL): 1.8 million hectares

Ratio of AL/Population*: 2.4

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

Commercialized Biotech Crops:
- HT Soybean
- Bt Maize

Total area under biotech crops and (%) increase in 2014:
1.6 Million Hectares (+7%)

Farm income gain from biotech, 2000 to 2013: US$147 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 2014 to reach 1.6 million hectares. A significant increase was recorded in the hectarage of herbicide tolerant soybean which occupies 100% of the national soybean hectarage of 1.55 million hectares. Biotech maize was planted on 90,000 hectares in 2014, compared to 140,000 hectares in 2013; a decrease mainly due to farmers substituting soybean, which is an easier crop to manage than maize. Uruguay planted maize for the eleventh year; 80% or 72,000 hectares of the biotech maize was the stacked Bt/HT product biotech maize which was first approved in Uruguay in 2003. Table 25 shows the biotech maize and soybean approvals from 2003 to 2014.

Table 25. Commercial Approvals for Planting, Food and Feed in Uruguay, 2003 to 2014

Crop	Event	Trait	Year
Maize	Mon 810	Insect resistance	2003
	Bt 11	Insect resistance	2004
	TC1507	Herbicide tolerance × Insect resistance	2011
	GA21	Herbicide tolerance	2011
	NK603	Herbicide tolerance	2011
	GA21 × BT11	Herbicide tolerance × Insect resistance	2011
	MON810 × NK603	Herbicide tolerance × Insect resistance	2011
	TC 1507 × NK603	Herbicide tolerance × Insect resistance	2012
	MON 89034 × TC1507 × NK603	Herbicide tolerance × Insect resistance	2012
	Bt11 × MIR162 × GA21	Herbicide tolerance × Insect resistance	2012
	MIR 162	Insect resistance	2014
Soybean	40-3-2	Herbicide tolerance	1996
	A-5547 - 127 (LL)	Herbicide tolerance	2012
	A-2704 - 12 (LL)	Herbicide tolerance	2012
	MON 89788 × MON87701 (Bt × RR2Y)	Herbicide tolerance × Insect resistance	2012
	CV127	Herbicide tolerance	2014

Source: Cámara Uruguaya de Semillas, 2014.

Uruguay approved five maize 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 (2011-2012), the efficient, science–based regulation system in Uruguay has approved a total of 11 products, emulating its neighbor Brazil which approved 14 products in two years, 2010 and 2011. In 2014, herbicide tolerant soybean CV127, insect tolerant corn MIR 162 and stacked Bt/HT MON 89034 × TC1507 × NK603 were approved for planting, for a total of 14 event approvals from 1996 to 2014.

In 2014, the regulatory system was working slowly with just some authorizations for trials. The lack of decision on GMOs was due to “internal affairs” in the Government with the upcoming election in October 2014.

Benefits from Biotech Crops in Uruguay

Uruguay is provisionally estimated to have enhanced farm income from biotech soybean and maize of US$147 million in the period 2000 to 2013 and the benefits for 2013 alone is estimated at US$25 million (Brookes and Barfoot, 2015, Forthcoming).

BOLIVIA

> **RR®soybean was grown on an estimated 1.0 million hectares in 2014 in Bolivia, similar to last year (2013). The adoption rate of RR®soybean in 2014 was estimated at 83% of the total 1.2 million hectares, similar to 2013. In 2008, Bolivia became the tenth country to officially grow RR®soybean, at 600,000 hectares. Thus, the growth rate between 2008 and 2014 has been significant with almost a doubling of RR®soybean hectarage. It estimated that provisionally, the economic gains from biotech crops for Bolivia for the period 2008 to 2013 was US$538 million and US$103 million for 2013 alone.**

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.

Soybean production started to expand in Bolivia in the early 1980s. Soybeans contribute to 4.6% of GDP and 10% of total exports. Most of the production is exported to the Andean region. The only genetically modified (GM) crop that has been approved for production or human consumption in Bolivia is Roundup Ready®(RR) soybean, which is resistant to the herbicide Roundup. The first approved crop was planted in 2005, but farmers had already introduced RR® soybeans from Brazil through family networks. 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.

RR®soybean was grown on an estimated 1.0 million hectares in 2014 in Bolivia, similar to last year (2013). The adoption rate of RR®soybean in 2014 was estimated at 83% of the total 1.2 million hectares, similar to 2013. In 2008, Bolivia became the tenth country to officially grow RR®soybean at 600,000 hectares. Thus, the growth rate between 2008 and 2014 has been significant with almost a doubling of RR®soybean hectares.

Certified Seed in Bolivia

BOLIVIA

Population: 10.1 million

GDP: US$23.9 billion

GDP per Capita: US$5,100

Agriculture as % GDP: 10%

Agricultural GDP: US$2.4 billion

% employed in agriculture: 32%

Arable Land (AL): 3.9 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 2014:
1 Million Hectares (0)

Farm income gain from biotech, 2008 to 2013: US$538 million

*Ratio: % global arable land / % global population

It is not a well recognized fact that the seed industry business in Bolivia is exemplary in the organization and use of certified seeds. IFPRI reports that 97% of the soybeans in the country 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. 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. Local, private input dealers and producer organizations are currently the source of approximately 21 herbicide tolerant (HT) soybean varieties.

It is estimated that RR®soybean was grown on 83% or 1.0 million hectares of the estimated total hectarage of 1.2 million hectares of soybean planted in Bolivia in 2014, similar to 2013.

According to the most recent estimates of global hectarage of soybean (FAO, 2014), Bolivia ranks eighth in the world with 1.2 million hectares, after the USA (31 million hectares), Brazil (28), Argentina (19), India (12), China (6.6), Paraguay (3), and Canada (1.8). Of the top eight soybean countries, six (USA, Argentina, Brazil, Paraguay, Bolivia and Canada) grow RR®soybean. Exports of soybean products from Bolivia in 2011 were worth US$402 million for cake of soybeans, US$282 for soybean oil, and US$13.1 million for soybeans.

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 23.9 million hectares of RR®soybean) and Paraguay (currently at 3.2 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.

Adoption of Biotech Soybean

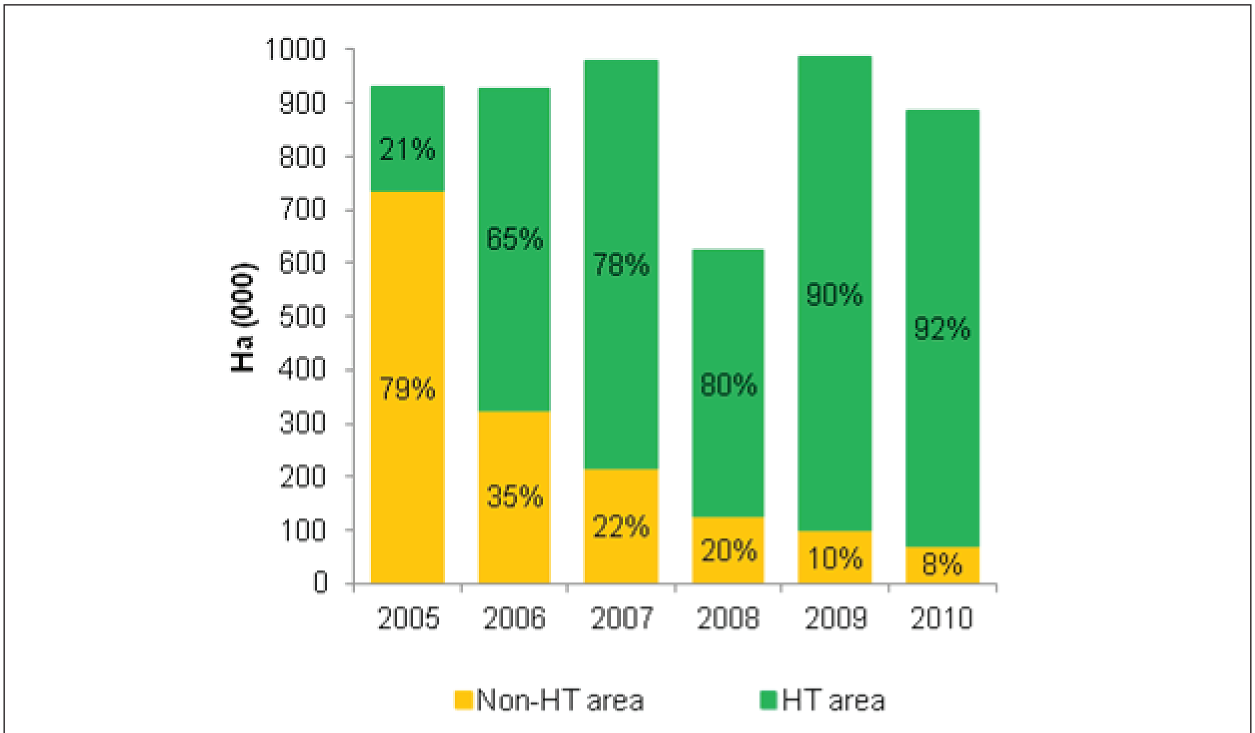
Adoption of soybean in Bolivia is depicted in Figure 22 (Smale et al 2012). Soybean hectarage has increased impressively from 1991 to 2005 and production has stabilized at around 1.6 million metric tons. A decreased hectarage occurred in 2008 because of poor weather conditions – El Niño, followed by La Niña. In 2007, the value of soybean exports was US$400 million, representing 8.5% of the total value of exports from the country; soybeans placed third in total export value, after natural gas and minerals. By 2010, the value of soybeans exports had grown to US$554 million (INE, 2011).

The percentage of area planted to transgenic soybean also rose steadily since its informal introduction by farmers and official approval in 2005 (Figure 22). According to ANAPO, the estimated area share of HT soybeans was 21% in 2005, 78% in 2007, and 92% in 2010 (Zeballos-Hurtado, 2011). Smallholders have a major presence in Bolivian soybean production. Since soybean production is fully mechanized and extensive, a smallholder is defined in Bolivia as a farmer who plants fewer than 50 hectares of the crop. In the year of the study, ANAPO estimated that there were 14 million soybean producers in the country, of which 77% operated on a scale under 50 ha ("smallholders"), 21% farmed between 51 and 1,000 ha, and only 2% managed more than 1,000 ha (Zeballos-Hurtado, 2011).

After the enactment of Bolivia's Law of Mother Earth and GMO ban, farmers have earnestly sought for reconsideration. In an article published by Reuters (November 2012), Bolivian soy farmers were urging President Evo Morales to reconsider the ban because of its serious economic repercussions to farmers and the industry. Growers also said that the regulations may also threaten the production of other crops such as corn, sugar, rice and sorghum which farmers use in rotation with soybeans, they say that could drive up food costs in South America's poorest country. This could also compound the impact of high transport costs in the landlocked country that make it harder to compete (Reuters, 1 November 2012).

However on June 6, 2013, the Bolivian government announced that it will expand the production of genetically modified foods beyond transgenic soybeans. Minister of Autonomy Carlos Romero Bonifaz gave an extensive presentation on the project which aimed to increase food production to ensure Bolivia's domestic supply as well as to increase the number of crops available for export. He stated that even though the new law will give priority to the production of organic foods, the government is conscious that ***"this is not enough to guarantee sufficient domestic food supplies nor allocate surplus for exportation"*** (Bolivia Weekly. 6 June 2013).

Figure 22. Percentage Distribution of HT and Non-HT Soybean Areas Planted in Bolivia, 2005-2010



Source: Zeballos-Hurtado, H. (2011).

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 26) 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.

It is provisionally estimated that the economic gains from biotech crops for Bolivia for the period 2008 to 2013 was US$538 million and US$103 million for 2013 alone (Brookes and Barfoot, 2015, Forthcoming).

Table 26. 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 2014, the area planted to biotech maize in the Philippines is projected to increase to 831,000 hectares, up 5% from the estimated hectares of biotech maize in 2013 of 795,000. Notably, the area occupied in 2014 by the stacked traits Bt/HT maize is 761,000 compared with only 712,000 hectares in 2013 and occupying 95% of total biotech maize hectares in 2014. This reflects the preference of farmers for stacked traits and the superior benefits they offer over a single trait. The number of small resource-poor farmers, growing on average 2 hectares of biotech maize in the Philippines in 2014 was estimated at 415,000 up significantly by 17,500 from 397,500 in 2013. Farm level economic gains from biotech maize in the Philippines in the period 2003 to 2013 is provisionally estimated at US$470 million and for 2013 alone at US$92 million.

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 2014 to reach 831,000 hectares, up 5% from the 795,000 hectares of biotech maize in 2013 (Figure 23). Notably, the area occupied by the stacked traits of Bt/HT maize has continuously increased every year reaching 761,000 hectares in 2014, compared with only 721,000 hectares in 2013, up by a substantial ~6%, 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. Total hectarage planted to the single trait Bt maize declined to 32% from 2008 to 2009, to 76% in 2012, with a total of only 3,000 hectares, and in 2013 and 2014, no single trait Bt maize has been planted. Single trait herbicide tolerant (HT) maize was planted on 70,000 hectares in 2014, which is only 8.4%, of the total biotech maize planted in the country, 14% lower than last year. 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 63% in 2014 (up from 62% in 2012). 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.

PHILIPPINES

Population: 94.9 million

GDP: US$225 billion

GDP per Capita: US$2,370

Agriculture as % GDP: 13%

Agricultural GDP: US$41.1 billion

% employed in agriculture: 33%

Arable Land (AL): 5.4 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 2014:
0.813 Million Hectares (+2.2%)

Increased farm income for 2003-2013: US$470 million

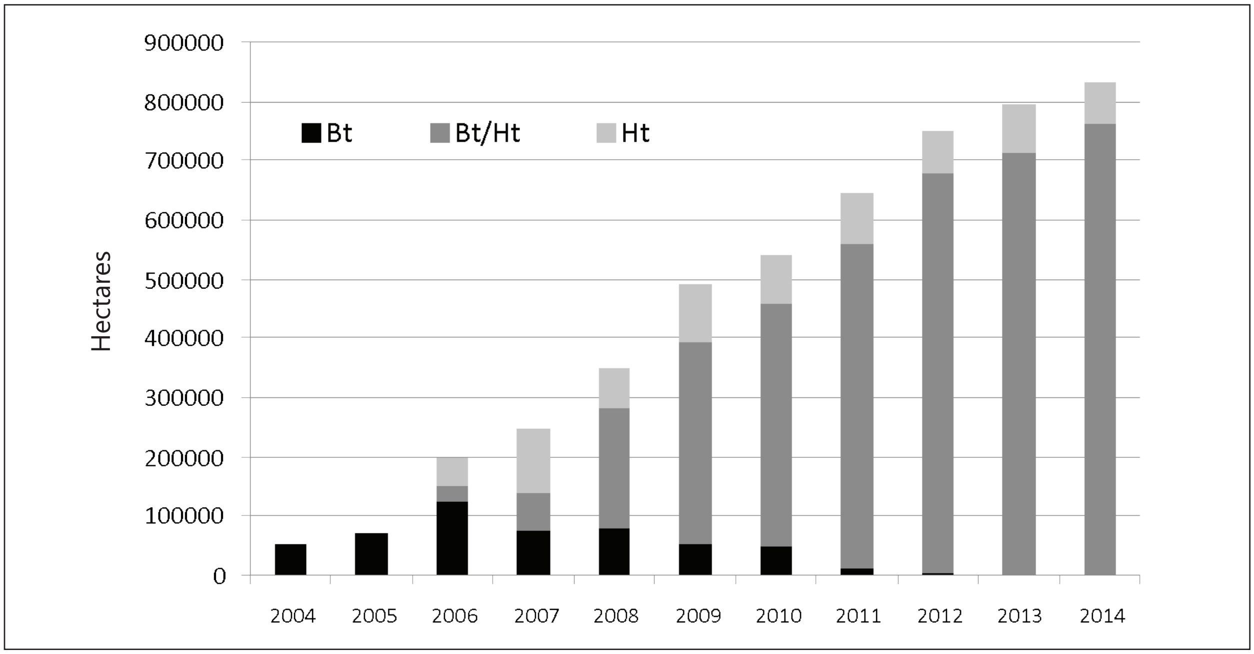
*Ratio: % global arable land / % global population

The number of small resource-poor farmers, growing on average 2 hectares of biotech maize in the Philippines in 2014, was estimated at 415,000 up significantly by 17,500 from 397,500 in 2013.

A total of 13 events of biotech maize are approved for commercial planting in the Philippines since 2002 (Table 27). In addition, a total of 75 biotech crops and products currently approved for direct use as food, feed and for processing in the Philippines that include alfalfa, canola, cotton, maize, potato, rice, soybean, and sugar beet.

The Philippines continues to be in the forefront of biotech research and commercialization in the region, as well as a model for science based and thorough regulatory policy. Biotech maize has been planted since 2003 and the country is gearing up for the possible commercialization of products of public-private sector collaboration such as Golden Rice, Bt eggplant, virus resistant papaya and Bt cotton.

Figure 23. Increase in Hectarage of Biotech Maize in the Philippines and Proportion of Commercialized Traits, 2003, 2014



Source: Compiled by ISAAA, 2014.

Table 27. Approval of Biotech Maize Events in the Philippines, 2002 to 2014

Crop	Trait	Year of Approval/Renewal
MON810	IR	2002/2007
MON863 x MON810	IR	2004
NK603	HT	2005/2010
Bt11	IR	2005/2010
MON810 x NK603	IR/HT	2005/2010
GA21	HT	2009
Bt11/GA21	IR/HT	2010
MON89034	IR/HT	2010
MON89034 x NK603	IR/HT	2011
TC1507	HT	2013
TC1507 x MON 810	HT/IR	2014
TC1507 x MON 810 x NK 603	HT/IR	2014
TC1507 x NK 603	HT	2014

IR: Insect resistance, HT: Herbicide Tolerance
Source: Compiled by ISAAA, 2014.

Golden Rice (GR) is a biotech rice biofortified with provitamin A beta carotene that is being developed by the Philippine Rice Research Institute (PhilRice) and the International Rice Research Institute (IRRI). The International Rice Research Institute (IRRI) reports that as of March 2014, the research, analysis and testing of beta carotene-enriched Golden Rice continues, in partnership with collaborating national research agencies in the Philippines, Indonesia, and Bangladesh. The first generation Golden Rice (GR1) was first tested in advanced field trials in IRRI in 2008 but due to low beta carotene, and second generation of Golden Rice event R (GR2-R) introgressed into selected mega varieties were field tested in the wet season of 2010. At PhilRice, confined field tests of advanced GR2 introgressed lines were conducted in February to June 2011. Selected lines were subjected to multi-location field trials in 2012 and 2013 for three seasons 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. It was expected that regulatory data required for biosafety approval for direct use could be submitted in 2013, to be followed later for an application for propagation. An eventful uprooting of one of the sites of the Golden Rice field trial by some 400 activists took place on 9 August 2013. This was the third season of the multi location field trial and the project team.

Preliminary results of the conducted multi locational trials are mixed. While the target level of beta-carotene in the grain was attained, yield was on an average lower than yields from comparable local varieties already preferred by farmers. Thus, an important goal of the trials was to test whether the agronomic performance of the new rice variety would be acceptable to farmers. Hence the new objective of increasing yield became the focus of the current research to include other versions of GR2 such as GR2-E and others. At IRRI, the Golden Rice trait is being bred into mega varieties to get suitable advance lines, and once attained, the series of confined field trials will resume. IRRI and its many research partners remain committed to developing a high-performing Golden Rice variety that benefits farmers and consumers. The important mission of the Golden Rice project – to contribute to improving the health of millions of people suffering from micronutrient deficiency – demands that every step and aspect of the scientific study of Golden Rice produces good results. IRRI and all participating organizations will continue to rigorously follow all biosafety and other regulatory protocols in continuing the research to develop and disseminate Golden Rice (IRRI, 24 March 2014).

The fruit and shoot borer resistant Bt eggplant project is led by the Institute of Plant Breeding of the University of the Philippines at Los Baños (IPB-UPLB), with the technology donated royalty-free by the Maharashtra Hybrid Seed Company (Mahyco) through a sublicense agreement. The proponents already completed field trials of promising hybrid varieties in the approved multi-location trial sites in Luzon and Mindanao in October 2012. The multi-location field trials have already generated the data required for biosafety assessment by the Philippine regulatory agency. Field trials of isoline non-Bt hybrids and open-pollinated varieties were conducted in six trial sites in Luzon, Visayas and Mindanao for purposes of selecting candidate lines for variety registration to the National Seed Industry Council. Data generated from these trials clearly showed that Bt eggplant provides an environmentally benign alternative to the current excessive use of chemical insecticide in local eggplant production. In addition, higher marketable yield potential and lower percentage EFSB-damaged fruits were obtained compared to the hybrid check.

In May 2012, Greenpeace and other anti-biotech environmentalists and politicians lodged a petition to the Supreme Court calling for the imposition of Writ of Kalikasan and issuance of a Temporary Environmental Protection Order (TEPO) opposed to the conduct of the Bt eggplant field trials. The respondents include government agencies such as the Environment Management Bureau of the Department of Environment and Natural Resources and the Bureau of Plant Industry and Fertilizer and Pesticide Authority of the Department of Agriculture. Other respondents include the University of the Philippines Los Baños, UPLB Foundation, Inc., and ISAAA. The petition was remanded by the Supreme Court to the Court of Appeals which heard the case, with the respondents jointly filing arguments against the petition. After almost a year of proceedings, the Court of Appeals issued a decision on 17 May 2013 granting the petition for a Writ of Kalikasan against the Bt eggplant field trial, principally anchoring its decision on the precautionary principle, and directing the respondents to cease and desist from conducting the field trials. Respondents filed a motion for reconsideration but on September 20, 2013, the Court of Appeals re-affirmed its earlier decision. Respondents appealed the case to the Supreme Court and are doing their best to attain an immediate and acceptable conclusion.

According to academia, industry and local government sources, the Bt eggplant case and the vandalism of the Golden Rice tests have provided the incentive for local stakeholders and scientists to coordinate educational outreach activities to promote the safe and responsible use of biotechnology.

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. Another field trial is being planned to be conducted in a larger area in 2014, pending release of regulatory approvals and research funds.

Bt cotton is being developed by the Philippine Fiber Development Administration (PFIDA, formerly the Cotton Development Authority). The technology, provided by Nath Biogene Ltd. and the Global Transgene Ltd. from India was tested for the first time in a confined field trial in 2010, started multi location field trials in 2012, and in 2013, data to complete regulatory dossiers were collected for commercialization purposes in two years' time. In mid 2014, the bioefficacy of Bt cotton hybrids against the cotton bollworm were reaffirmed in another field trial. 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 products that will emerge from the public sector 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 32.2% of the global 184 million hectares of maize with China itself growing 32 million hectares, plus significant production in India (9.5 million hectares), Indonesia (4), Philippines (2.6), Vietnam (1.2), Pakistan (1.2) and Thailand (1) (FAO, 2014).

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 2013 is estimated provisionally to have reached US$470 million. For 2013 alone, the net national impact of biotech maize on farm income was estimated at US$92 million (Brookes and Barfoot, 2015, 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 years, 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$470 million, provisionally from biotech maize in a short span of ten years, 2003 to 2013 (Brookes and Barfoot, 2015, Forthcoming), and is advancing the adoption of the maize stacked traits, IR/HT. In 2014, stacked traits in maize represented around 90% 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 2 years including Bt eggplant in 2014/15 and with a reasonable possibility that the Philippines might also be the first country to commercialize Golden Rice.

Adoption and Uptake Pathways of Biotechnology Crops in the Philippines

ISAAA commissioned a study on *Adoption and Uptake Pathways of Biotechnology Crops: The Case of Biotech Corn Farmers in China, India, and the Philippines (Hautea et al. 2013)*. A synthesis of the results in the Philippines is presented below.

> A study on the adoption and uptake pathways of biotech corn among small-scale, resource-poor Filipino farmers; and the changes these have brought to the farmers' lives was conducted in three provinces in the Philippines where the crop is mainly cultivated.
>
> The study revealed that farmers have been planting biotech corn for an average of 7 years, with 46.5% having adopted the crop from 6 to 10 years now. Farmers gave multiple reasons for adopting biotech corn. Among those that stood out and considered facilitating factors for adoption in decreasing order of importance were: high income, pest resistance, good grain quality, available financing, lesser production cost, and availability of seeds.
>
> Farmers have multiple sources of information on biotech corn, but these were dominated by interpersonal sources. Seed suppliers/traders ranked as the topmost (56.2%) information sources; followed by DA technicians (34.0%); and then by their co-farmers (30.3%). It should be clarified that while seed suppliers/traders were considered primary information sources, it was their co-farmers who influenced them to adopt biotech corn.
>
> ***Adoption Pathway of Biotech Corn***
>
> Using a participatory rural appraisal tool *Innovation Tree*, information about biotech corn was found to be first brought to the farmers' attention by the seed company technicians.

Through community meetings, the technician explained about biotech corn's advantages especially in terms of higher income and tried to prove this by establishing a demonstration farm in the village. Farmers were asked to observe the performance of the crop in the demo farm. Based on their own observations and learnings, farmers decided to try the corn variety themselves. Seed company technicians connected the farmers to financiers in the area; or the farmers themselves, through their local networks, sought out these financiers. Local-based cooperatives also participated in the endeavor by offering loan for capital or inputs at low cost to the farmers. In most cases, the financiers provided the entire needed farm inputs in cash or in kind (seeds, fertilizers, etc.) on loan basis. They also acted as the buyers/traders of the farmers' harvest at a price they set for farmers.

As farmers in one community succeeded in the biotech corn venture, they shared their experience to fellow farmers in other communities through word-of-mouth. Farmer-relatives and farmer-friends were the typical contact points. The "good news" then spread out to other nearby communities. Seed company technicians, financiers/traders, and, if present in the area, cooperatives also expanded their reach to these new areas and performed the same roles. Within each community, farmers continuously shared among themselves their experiences, good or bad, and tried to learn from their own encounters with the biotech corn. A common element in their stories was the fact that their income increased two- or three-fold as they adopted the biotech corn variety. An overwhelming majority (93.2%) expressed their intent to continue adopting biotech corn and this was primarily due to both material and non-material benefits they derive from it.

Problems Encountered by the Farmers

Problems encountered by biotech corn farmers include the occurrence of fungal/bacterial diseases and other pests (31.8%); expired seeds that did not germinate (19.8%); high cost of inputs (16.1%); low buying price of traders (8.1%); and lack of own capital (6.8%). Lack of capital is also a problem since few farmers who were not able to repay their loan were "blacklisted" by their financiers. With no capital, they could no longer avail of the expensive inputs, so they stopped. Others were discouraged by their initial try with seeds that did not germinate; so they backed out. Still others opted to go back to planting their white corn variety which according to them requires lesser capital, takes shorter time to harvest, edible for human food, and enables them to earn equal to or even higher than the biotech corn. They can also easily produce the needed seeds for their next cropping season from their harvest.

Recommendations for Increased Adoption

Based on the findings of the study, recommendations to enhance adoption and uptake of biotech corn among small-scale and resource-poor farmers may involve the provision of material inputs, technical assistance, and policies that would support farmers' adoption and uptake of biotech corn.

Farmers exhibit strong belief in themselves and are inspired by the success of their fellow farmers. Hence, farmer-to-farmer education must be promoted and sustained. People are more likely to follow the behaviors modeled by someone with whom they can identify with. The more perceived commonalities and/or emotional attachments between the observer and the model, the more likely the observer will learn from the model. Also, farmers need to be assisted in addressing the persistent crop pests and diseases other than borer that continuously attack their corn. Seminars may be given by experts on this concern to enable the farmers to understand and solve the problem on their own. Local agriculturists should also be informed so that they could accordingly assist the farmers.

Since the technology starts with the seeds, the government agencies such as Department of Agriculture (DA) may need to put up regulatory mechanisms so that private companies supplying the seeds would comply with certain standards. Right of the farmers to obtain good seed quality must be ensured and protected. Some policies and guidelines addressing seed expiry and other broader concerns such as the price and distribution of seeds and proper labelling of varieties need to be put in place.

The government also needs to intervene so that a minimum buying price of corn produce is set. This is to prevent the traders from abusing the farmers, especially those indebted to them in terms of capital. As the study revealed, the market and buyers are very important to avoid a glut in the face of bountiful harvest of biotech corn. While this role is being performed very actively by the traders, the government may explore setting up of alternative markets with competitive buying price of corn, so that farmers would not be trapped in a no-choice-except-trader situation.

To address the perennial problem of farmers' indebtedness to financiers/traders, an in-depth study on this practice and its alternatives should be undertaken. It would help analyze who the traders are, their unwritten codes and loaning systems, dynamics of their relations with farmers, co-traders, and other actors in the supply chain, among others.

Support from Stakeholders

Scientists and Policy Makers

Scientists from different institutions speak their opinions about the Philippine Court of Appeals order to permanently stop all field trials of Bt eggplant:

Dr. Emil Q. Javier, former president of the University of the Philippines (UP) and the National Academy of Science and Technology (NAST) said, ***"The CA order was a perverse application of the Writ of Kalikasan which intent is to assure the Filipino people of balanced and healthful ecology because this was precisely what the Bt talong research was trying to accomplish."*** He added that ***"Contrary to what Greenpeace and GMO technology detractors claim, the UN World Health Organization, the US National Academy of Science, the British Royal Science Society and many other prestigious National Science Academies consider consuming foods from GM crops***

'no riskier' than consuming same foods from crops modified by conventional plant breeding techniques."

Biotech Coalition of the Philippines President and Dean of the UP Manila College of Public Health, Dr. Nina Gloriani, also expressed her disappointment over the ruling: ***"confined field trials allow our scientists to better understand how biotech varieties grow in real-life conditions. Researchers have long taken government guidelines for confined field trials very seriously and have worked to minimize any risks to the environment and human and animal safety...Applicants who wish to conduct confined field trials have to follow strict guidelines and best industry stewardship practices. Our current biosafety laws already provide for a high standard of protection for the environment and human health, and a track record of more than a decade of field trials and commercialization of Bt corn"*** (Crop Biotech Update, 17 June 2013).

Philippine Food and Drug Administration Kenneth Hartigan-Go in a press release supports biotech crops. He said, ***"As the National Competent Authority, the FDA supports the robust science-based evaluation system of CODEX Alimentarius Commission using data and information from field trials as well as laboratory tests. For processed food, the main focus of food safety review is on the objective characteristics of the product and on any health or nutritional claims. The focus of evaluation is on the food product and not on the technology used to produce the product.***" She added that "***All food derived from GM crops in the market have met international food safety standards and are as safe as and as nutritious as the food derived from conventional crops for direct use as food, feeds and for processing"*** (Crop Biotech Update, 26 June 2013).

Farmer Experiences obtained from the Adoption Study (Farmers First, 2013)

Delson Sonza of Sara, Iloilo, Philippines
Farmers from our province are one of the early adopters of biotech corn. Iloilo is a mountainous province and some of its hilly grasslands are idle, thus there was a need to convert these grasslands to corn farms. Before biotech corn was commercialized in the country, farmers only earn during rice farming season (May-July), sugarcane planting season (October-January), and harvesting of rice and sugarcane (October -December).

In 2005, when glyphosate tolerant corn was introduced in the Philippines, dialogues with farmers in Iloilo were conducted to convert our grasslands into corn farms. With farmers convinced to adopt the biotech crop, technology transfer initiatives took place. The adoption of biotech corn was able to uplift our lives as farmers. This gave us an income of roughly Php30,000 (US$750) per hectare which is far higher than income derived from conventional corn. Also, we no longer need to plow and weed, hence, we have more time to find other means of livelihood. Because of higher income, we can now afford to buy appliances, renovate our houses from nipa hut to concrete shelters, and acquire service vehicles such as motorcycles or even a truck. We can also send our children to school and we can even invest in post harvest equipment.

Rosalie Ellasus of San Jacinto, Pangasinan, Philippines
I tried Bt corn after attending the Farmers' Field School. Our speaker had been telling us that we should

always choose good seeds. A seed company eventually conducted a Bt corn trial in a nearby town. During that time, infestation of ordinary corn in our place was so high. But with the Bt corn planted for the trial, I really saw that crops were so healthy. There was not even a trace of pests considering that they did not apply insecticide. Furthermore, you no longer need to visit your corn field everyday and this gives you peace of mind. The production cost will be lessened as well compared to conventional corn farming and the yield will be more. This is why I adopted Bt corn.

Pablito Lobendino of Villapaz, Naguillan, Isabela, Philippines
Seed company technicians introduced biotech corn varieties to us. They said these varieties are good to plant because it minimizes the cost of farming especially in removing weeds. When we tried biotech corn, it indeed reduced our production cost. The yield is also higher. We still plant ordinary corn from time to time when the Department of Agriculture (DA) provides seeds but farming inputs are expensive. When we were not yet planting biotech seeds, there was barely money left because you spend a lot particularly to remove weeds. When we started to plant biotech seeds, we earned a decent profit.

Indalencio Supan of Balitucan, Magalang Pampanga, Philippines
I have been farming since I was 20 years old and now I am already 73 years old. Before Bt corn was commercialized, I was planting sweet corn but the crop is prone to borer infestation. I learned about Bt corn through seed technicians from the government and private seed companies. They encouraged us to plant this variety to increase our earnings. We were convinced because Bt corn really yields more than the conventional variety as the latter is usually eaten by the corn borer. We started to plant Bt corn in 2003 and we are still planting it up to now. Because of planting Bt corn, we were able to buy a house and lot, farm machineries and even farm land. But we still want to learn more from seed technicians during seminars. We also look forward to government support especially in terms of financial assistance so that we can minimize borrowing from traders.

Aquino Gozun of Lacmit, Arayat, Pampanga, Philippines
We started to plant Bt corn in 2004. The Office of the Provincial Agriculturist organized a Farmers' Field School in our place where they also conducted farm demonstrations. I was one of the cooperators in their farm demo. That was the very first time I planted Bt corn. I initially saw the big difference between Bt corn and conventional corn. The pests always eat the conventional corn that's why we sometimes end up with no earning at all. When Bt corn was introduced to us, it brought good results to farmers as we no longer need to apply insecticide and we even have more yield. This gives us an income twice more than what we get from the conventional corn. That's why almost every farmer in my place is planting Bt corn.

Aurea Raso of Macayug, San Jacinto Pangasinan, Philippines
We have attended a lot of seminars on biotech corn farming from different seed companies. We were oriented on proper way of cultivating the crop, its traits, and its benefits. There were also farm demonstrations from seed companies and encouragement from progressive farmers in our village like Rosalie [Ellasus]. This is why we decided to try Bt corn. Bt corn is really good because we no longer have to spray insecticide to control the pests. With ordinary corn, you really need to apply insecticide because they are vulnerable to pests. There are also varieties which can tolerate herbicide. Adopting biotech corn indeed helped my family. When harvesting period comes, we are confident that we will have a sure earning.

Corazon Cabasag of Sta. Rosa, Iguig, Cagayan, Philippines
We started to plant Bt corn eight years ago when the government introduced the variety to us. They said that Bt corn cannot be infested by borers. Even if the seed's price is higher than ordinary corn, they said Bt's outcome will be far better. Then we attended their farm demo. Since then, we started to plant this variety. Bt corn indeed gives more yield than the ordinary corn since the latter is prone to borer infestation and you also have to apply insecticide. You will really see the big difference between ordinary corn and Bt corn. Because of Bt corn, we were able to acquire a big thresher.

Faustino Astrero Jr. of Banga, South Cotabato, Philippines
In our place, large seed companies organize a harvest festival for farmers. Aside from free food, they also give us samples of their products and they conduct seminars on Bt corn. When I started to plant Bt corn, I felt more relaxed because there is less labor in planting Bt corn unlike with conventional corn where you still need to till the land. One no longer needs to spray insecticide. It also reduces my time for corn farming and I can spend more time with my other crops. We also get higher yield from Bt corn.

AUSTRALIA

Compared with 2013, Australia grew about 200,000 hectares less Bt cotton in 2014 because of severe drought which was partially offset by more than 100,000 hectare increase in biotech canola for a net decrease in both biotech crops of ~100,000 hectares. More specifically, Australia grew 542,000 hectares of biotech crops in 2014, comprising ~200,000 hectares of biotech cotton (down from 416,000 hectares in 2013) plus 342,000 hectares of biotech canola (up from 222,000 in 2013) – this 342,000 hectares of HT canola is more than an eight-fold increase from the 41,200 biotech canola hectares in 2009. Reduction in biotech cotton planting is due to lower total cotton hectarage brought about by continuous drought, lower cotton prices and the shift to higher priced canola and other cereals. Notably, biotech cotton adoption remains at 99% of all cotton grown in Australia and ~95% of it featured the stacked traits (insect resistance and herbicide tolerance). The total biotech crop hectarage in 2014 represents an ~11-fold increase over the 48,000 hectares of biotech crops in 2007, during which Australia suffered a very severe drought. The drought 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. Provisional estimates indicate that enhanced farm income from biotech crops is at US$890 million for the period 1996 to 2013 and the benefits for 2013 alone at US$124 million.

Compared with 2013, Australia grew about 200,000 hectares less Bt cotton in 2014 because of severe drought which was partially offset by more than a ~100,000 hectare increase in biotech canola for a net decrease in both biotech crops of ~100,000 hectares. In 2014, Australia grew 542,000 hectares of biotech crops, (down 15% from 638,000 hectares planted in 2013) comprising 200,000 hectares of biotech cotton, (down from 416,000 hectares in 2013), plus 342,000 hectares of biotech canola (up 54% from 222,000 in 2013). This compares with more than eight-fold increase from the 41,200 biotech canola hectares in 2009. The decrease in biotech cotton was due to decreased cotton plantings because of drought and lower cotton prices forcing farmers to shift to planting biotech canola and other cereals due to high prices. A remarkable 100% of all cotton grown in Australia in 2012 was biotech and 94.5% of it (189,000) featured the stacked genes for insect resistance and herbicide tolerance and 5.5% (11,000) are herbicide tolerant.

In 2014, Australia for the seventh year grew herbicide tolerant RR®canola in three states: New South Wales (NSW), Victoria and Western Australia. According to the Australian Oilseeds Federation (2014), an estimated total of 2.2 million hectares of canola were grown in Australia, of which 21% of 1.2 million hectares (255,600 hectares) biotech canola were grown in Western Australia, 9% of 550,000 hectares (50,000 hectares) were biotech in NSW, and 9% of 400,000 hectares (36,400 hectares) were biotech in Victoria. Biotech canola planting at 342,000 hectares is 14% adoption rate in 2014 compared to 9% in 2013. There is a potential 1.8 million hectares in Australia that can be planted to biotech canola for the benefit of the farmers and consumers in the country (Table 28).

AUSTRALIA

Population: 22.6 million

GDP: US$1,379 billion

GDP per Capita: US$61,790

Agriculture as % GDP: 2%

Agricultural GDP: US$27.58 billion

% employed in agriculture: 3%

Arable Land (AL): 42.2 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/F/HT-F Canola

Total area under biotech crops and (%) increase in 2014:
0.542 Million Hectares (-15%)

Farm income gain from biotech, 1996-2013: US$890 million

*Ratio: % global arable land / % global population

The total biotech crop hectarage of 542,000 hectares in 2014 represents a ~11-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. Reduced crop planting in Australia is affected by the lack of rainfall to replenish irrigation shortage as well as soil moisture in dry land systems. Figure 24 shows the long term average area in Australia where drought in 2007 immensely dropped the area cultivated to crops to 60,000 hectares. Ample rainfall and even floods, as well as good prices spiked the area cultivated in 2011 to more than 700,000 hectares. It is estimated that with good rain in the next 10 months, cultivation area could return to >500,000 ha in 2014/15, otherwise, it could be back to 250,000 (CSIRO, Personal Communications).

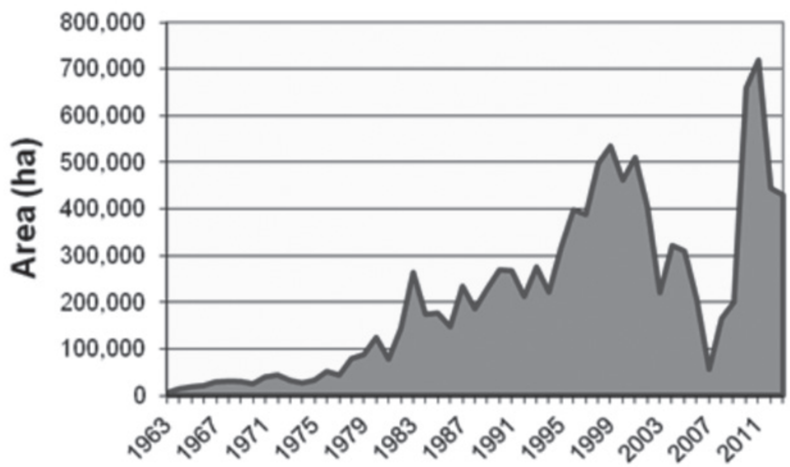
It is also important to note that Australia's first dual trait herbicide tolerant canola varieties are set to be released in 2015. The varieties will contain triazine and glyphosate tolerance traits (RT). The RT products will be available through Pacific Seeds. Australian canola farmers are anticipating this new

Table 28. Hectares of Canola, Conventional and RR® Biotech Planted in Australia, by State, 2013 and 2014

State	Total Canola (Ha)		Biotech Canola (Ha)		Biotech Canola (%)		Non-Biotech
	2013*	2014*	2013**	2014**	2013	2014	2014
NSW	600,000	550,000	31,573	50,000	5%	9%	500,000
Victoria	400,000	400,000	21,232	36,400	5%	9%	363,600
Western Australia	1,180,000	1,225,000	167,596	255,600	14%	21%	969,400
Total	**2,180,000**	**2,175,000**	**222,414**	**342,000**	**9%**	**14%**	**1,833,000**

* Sourced from Industry Data, compiled by Australian Oilseeds Federation
** Area estimate of Biotech canola based on seed sold using a 2.5kg/Ha seeding rate

Figure 24. Cultivated Area of Cotton in Australia as Affected by Rainfall Patterns



Source: CSIRO, Personal Communication

pyramided herbicide tolerant product because it will provide a good suite of tools in terms of weed management. The technology will be another alternative for chemical rotation to prevent herbicide tolerance. More than 500 agronomists and consultants have witnessed the efficacy trial of the new product in Australia (Crop Biotech Update, 15 October 2014).

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. In 2014, 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 11 biotech wheat research project field trial licenses approved in Australia from 2007 to 2014 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 increased nutritional 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).

Field trial applications and approvals as well as map of trial sites are available to the public through the OGTR website. Public trust to the Australian system of GMO approval has been high due to its transparency and science-based regulatory system.

New initiatives on wheat research include the further development of bacterial and fungal resistance by scientists at Swinburne University of Technology. The team designed artificial peptides that mimic the ones found in grains and tested them against various bacteria, fungi and mammalian cells. They found that the peptides were aggressive towards a range of bacteria and fungi, but left mammalian cells unharmed, and could be used in any area that aims to reduce microbial contamination, such as food safety, hygiene and surface decontamination. The peptides also tolerate high heat and can be used as preservatives in food applications, such as milk or orange juice (Crop Biotech Update, 19 March 2014).

Biotech Sugarcane

Biotech sugarcane is not yet grown commercially in Australia; however, the OGTR (2014) has issued four 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 by the University of Queensland and BSES Ltd., a sugarcane research and development institution in Australia.

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. Philanthropist 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).

The GM fruit from Australia could turn East African nations into life-saving banana republics. They have successfully modified the fruit and are now being tested on humans. In 2014, the GM bananas, with orange flesh, were shipped to Iowa State University for trials. Five Ugandan PhD students are working with Professor James Dale on the project funded by the Bill and Melinda Gates Foundation. It is hoped that by 2020, vitamin A-enriched bananas would be grown in Uganda, where about 70% of the population survives on the fruit. The highland or East African cooking banana is a staple food of many East African nations but it has low levels of micronutrients including pro-vitamin A and iron. Dale and his team aim to increase the level of pro-vitamin A in that banana. When field trials in Uganda are in place, the same technology could be transferred to countries such as Rwanda, parts of the Democratic Republic of Congo, Kenya and Tanzania (Crop Biotech Update, 20 August 2014).

Drought Tolerant Legumes

Crops in Australia have been badly affected by the frequently occurring extreme drought conditions. Hence, drought tolerant mungbean is being developed at University of Western Australia QUT where researchers are enhancing the root architecture of the mungbean plant to make the root system deeper and more volume so it can spread over a wider area – a technology for more access to water and nutrients. The technology has been used in sorghum and the scientists are optimistic that it will also be applicable to mungbean to be able to grow on specific environments (Crop Biotech Updates, 4 June 2014)

Benefits from Biotech Crops in Australia

Provisional data indicate that Australia is estimated to have enhanced farm income from biotech cotton by US$890 million in the period 1996 to 2013 and the benefits for 2013 alone is estimated at US$124 million (Brookes and Barfoot 2015, 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.

Stakeholder Support to Biotech Crops in Australia

Australia's Agriculture Biotechnology Council (ABC) Julian Little stated that there was an overwhelming weight of evidence on the safety of GM crops. He opined that ***"Every legitimate scientific organization that has examined the evidence has arrived at the conclusion that GM crops and the foods they produce pose no risk to human health or the environment beyond those posed by their conventional counterparts"*** (Farmer's Weekly 25 October 2013).

In a study by the Commonwealth Scientific and Industrial Research Organization (CSIRO) released by author Craig Cormick showed that there is generally a high level of interest and trust in science in Australia. They also found minimal impact of negative media coverage on science and research organizations. It was also noted in the report that pro-science and technology values are strong predictors of support for even controversial topics such as GM foods. The other key findings of the study include the following points:

- Television is the most popular source of information on science and technology. Those with high interest in science and technology favor getting information online.
- Almost half of the population are not interested in science, and the younger generations are becoming increasingly unengaged on science.
- Attitudes to science in schools are a major predictor of attitudes to science in later life. (Crop Biotech Update, 2 July 2014)

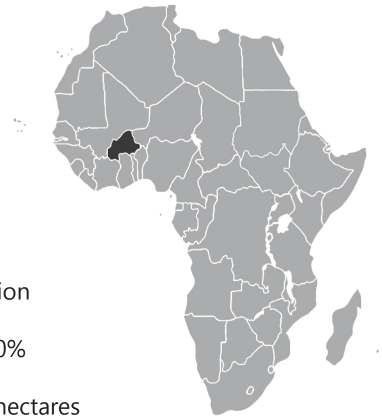
A related study on GM crop attitude was investigated by Matthew Marquez of La Trobe University, Australia, and colleagues. It showed that in 8,000 Australians surveyed over 10 years, positive attitudes towards various GM organisms for food were high for plants due to higher trust in scientists and regulators and lower trust in environmental organizations (Crop Biotech Update, 10 September 2014).

The landmark case in Australia involving GM farmer Michael Baxter accused of contaminating his neighbor's crops with genetically modified (GM) canola was in the West Australian Supreme Court. Baxter was sued by his neighbor Steve Marsh, an organic certified farmer who alleged that his farm in the Great Southern region was contaminated by GM material blown onto his property from Baxter's land. Marsh claimed that the contamination caused him to lose his organic certification on more than half his property in Kojonup, south of Perth, for almost three years. But Justice Kenneth Martin said Mr. Baxter could not be held responsible just for growing a GM crop in a conventional way. Justice Martin added in his judgment summary that the ends of season winds and the blowing of swathes from Sevenoaks eastwards into Eagle Rest had not been an outcome intended by Mr. Baxter and that he was not to be held responsible as a border area farmer merely for growing a lawful GM crop and choosing to adopt a harvest methodology (swathing) which was entirely orthodox in its implementation (Crop Biotech Update, 11 June 2014). The decision is reflective of how science and political will work together to resolve issues and court cases on GM crops that are rapidly increasing in many parts of the world. Thus, vigilance and support from the learned are essential in these instances.

BURKINA FASO

2014 was the seventh year for farmers in Burkina Faso to benefit significantly from Bt cotton. A total of 454,124 ha out of a total of 648,469 hectares or 73.8% were planted to Bt cotton (BGII) in the country in 2014. This represents a 5% increase in adoption from the 68.6% in 2013. Based on an average cotton holding of 3.16 hectares the number of farmers growing Bt cotton in 2014 was approximately 143,710. Farmers remained steadfast in their quest to expand their Bt cotton farming. A notable achievement in Burkina Faso in 2014 was the formalization of a women farmers association to encourage more women to take up Bt cotton growing and ensure access to extension services. Adoption of Bt cotton (Bollgard II™) has therefore taken a gender dimension meaning more women farmers will in the future be key players in the now highly competitive sector. Documented farmer benefits include a 20% yield increase compared to conventional cotton, pesticide use reduction of about 67%, while cotton profits was elevated by US$64 per ha, which is a 51% increase over current income levels.

BURKINA FASO



Population: 17 million

GDP: US$10.4 billion

GDP per Capita: US$1,300

Agriculture as % GDP: 33%

Agricultural GDP: US$3.4 billion

% employed in agriculture: 90%

Arable Land (AL): 5.7 million hectares

Ratio of AL/Population*: 2

Major crops:
- Cotton
- Millet
- Peanuts
- Maize
- Sorghum
- Rice
- Shea nuts

Commercialized Biotech Crops: Bt Cotton

Total area under biotech crops and (%) increase in 2014:
0.454 Million Hectares (+4%)

Farm income gain from biotech, 2008-2013: US$137 million

*Ratio: % global arable land / % global population

Bt cotton production in Burkina Faso enjoys the government's full support and a very well organized producers association, the UNPCB – Union Nationale des Producteurs de Coton du Burkina. Cotton remains the country's principal cash crop, generating over US$300 million in annual revenues. This represents over 60% of the country's export earnings and 20% of GDP (ICAC, 2013; African Cotton Companies Bulletin 2012). The cotton sector in the country has been undergoing various policy reforms and one distinct outcome is an overall best growth performance among the West African states during the last decade. Reforms have been more successful in Burkina Faso than in other francophone countries. The greater success of the privatization effort in Burkina Faso is due to a combination of good governance and the unique geographic situation in the country with three distinct production zones that leads naturally to a trisected system of input supply and seed cotton procurement. The stabilization of the institutional landscape, stakeholder accountability in governance of the sector, the use of better technology and the adoption of efficient practices are keys to the success of Burkina

Faso cotton program. Exports of cotton have ranged from 775,000 bales to 1.4 million bales per year.

It is estimated that continued adoption of Bt cotton will generate an economic benefit of more than US$70 million per year for Burkina Faso, based on yield increases of 20%, plus a two-thirds reduction in insecticide sprays, from a total of 6 sprays required for conventional cotton, to only 2 for Bt cotton. The real and potential economic impacts of insect resistant cotton are therefore highly significant as increases in the prices of agricultural inputs used to combat destructive cotton pests remain a major challenge in the other West African states that have not embraced the technology.

2014 was the seventh year for farmers in Burkina Faso to benefit significantly from Bt cotton. Out of a total of 648,469 hectares planted to cotton in the country in 2014, 454,124 hectares or 73.8% were planted to Bt cotton (BGII). Total cotton planted in 2014 was 648,469 hectares equivalent to 73.8% adoption (Table 29). Based on average cotton holding of 3.16 hectares the number of farmers growing Bt cotton in 2013 was approximately 143,710. A notable achievement in Burkina Faso in 2014 was the formalization of a Bt cotton women farmers' association to encourage more and more women to take up Bt cotton growing and ensure access to extension services. Adoption of Bt cotton (Bollgard II™) has therefore taken a gender dimension meaning more women farmers will in the future be key players in the now highly competitive sector. Documented farmer benefits include a 20% yield increase compared to conventional cotton, pesticide use reduction by about 67%, while cotton profits was elevated by US$64 per ha, which is a 51% increase over current income levels.

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 poverty. The scientific work to evaluate performance and selection of the two approved varieties was conducted 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 company (Monsanto) has been issued a new authorization from the National Biosafety Authority (NBA) to continue commercialization of Bt cotton for another ten years (2013-2023). Meanwhile, the NBA will perform socio-economic studies on Bt cotton.

Burkina Faso continues to take the lead 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 is serving as a model for many other developing countries growing cotton as well. As the pioneer in the sub-region, the country 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. The Ghanaian government for example has already initiated multi-location

Table 29. Bt cotton Adoption in Burkina Faso for 2014-2015

Cotton Company	BG II	Conventional	Total	Adoption Rate
Sofitex	367,801	163,219	531,020	69.26
Socoma	50,140	25,000	75,140	66.73
Faso Coton	36,183	6,126	42,309	85.52
Total	**454,124**	**194,345**	**648,469**	**73.84**

Source: Compiled by ISAAA, 2014.

trials for Bt cotton (Bollgard II™) in six locations in the Northern part of the country bordering Burkina Faso.

There has been heightened awareness and demand from farmers in neighboring countries such as Benin, Cote de Ivoire, Ghana, Nigeria and Togo for Bt cotton and are urging their governments to facilitate the process. This is an indication that the Burkina Faso experience is inspiring more and more countries into putting governance mechanisms for safe use of modern biotechnology. On its part, SOFITEX, the largest of companies involved in selling the Bt cotton seed is planning to produce enough Bt seeds to sell to other cotton companies and to the neighbouring countries that have expressed a demand.

Benefits of Biotech Crops in Burkina Faso

It has been estimated that Bt cotton has the potential to generate an economic benefit of up to US$70 million per year for Burkina Faso. According to a survey report of International Monetary Fund (IMF), Burkina Faso's exports tripled over the last 10 years. Index Mundi, which monitors commodity prices, confirms that cotton production in Burkina Faso had gone down to almost 50% before Bt cotton was commercialized. When Bt cotton was planted in 2008, the production increased significantly. Cotton production in the country increased by 57.5 percent in 2012, as reported by Burkina National Cotton Producers Union (UNPCB) and the country obtained more than US$1 billion from the sale of cotton in 2012. The Government also reported a sharp increase in 2012/13 seed cotton production, anticipated to reach 630,000 tons during 2012/13, a 52 percent increase from 2011/12. In 2013/2014, a 68.6% adoption rate was recorded, which subsequently went up by 5% to 73.8%. This high adoption is due to better yield of Bt cotton – about 1.1 tons per hectare compared to less than 1 ton per hectare for previous years. This resulted from the implementation of a plan to increase the purity of Bt seeds, selecting 5,000 seed multipliers to produce good quality Bt cotton seed, and having more farmers apply better agronomic practices that includes incorporating more organic fertilizer. Bt cotton accounted for around 70 percent of total production harvested on roughly 454,124 hectares in 2014. Provisionally, economic gains for 2008-2013 is US$137 million and US$37 million for 2013 alone (Brookes and Barfoot, 2015, Forthcoming).

Farmer Testimonials

Interview with Mrs. Zouma Salimata, Woman farmer, Pegwende farming group (GPC), Nematoulaye village, Houet Province, Burkina Faso

Mrs. Zouma Zalimata is a mother of 4 and married in a polygamous home. She started farming Bt cotton in 2008 and was a founding member of the Pegwende Women's farming group, formed in 2008. In 2009, the group got official recognition by SOFITEX – the biggest cotton company in Burkina Faso. This meant extended privileges for reliable supply of seeds, fertilizer and other inputs on credit. Mrs. Salimata has a 4 hectare farm of Bt cotton to her name, and together with her group of 22 other members, own 61 hectares on which they have cultivated 42 hectares of Bt cotton and the remaining to conventional cotton. SOFITEX has given the women farmers the freedom to choose between Bt cotton and conventional cotton depending on the investment one wants to make.

"Together with majority of the members in the group, we chose Bt cotton because it requires less spraying, is easier for us women to take care of and saves some time for us to do other household chores – freedom is the word" she proudly says. The mother of 4 young children further argues that even when the soil is not very fertile, Bt cotton will yield a harvest. ***"In 2013, I harvested 2.5 tons of Bt cotton per hectare, which was far beyond my expectation."*** Other advantages she attributes to Bt cotton include prime maturing with most balls intact and better returns. ***"Bt cotton has empowered me and my fellow members... Our lives are slowly improving from abject poverty to some level of decency. We can now help our husbands to pay school fees for our children, buy our own clothes and kitchen utensils,"*** she prides. Zalimata attributes most of her success to the fact that she belongs to a recognized farmer group, which gets grants and frequent training on best agricultural practices.

MYANMAR

Agriculture is important to Myanmar, contributing more than 50% to GDP and employs more than half the work force – it has benefited from planting biotech cotton for almost ten years. The insect resistant Bt cotton variety "Silver Sixth" or "Ngwe chi 6" occupied 318,000 hectares, up 13,000 hectares from 2013, and equivalent to an adoption rate of 88% on the 360,000 hectares of cotton grown in Myanmar in 2014. Approximately 454,000 small holder farmers (average of 0.7 hectare of cotton farm per farmer) planted the long staple Bt cotton variety in the ninth consecutive year of cultivation, 2006 to 2014. In 2014, the Bt cotton variety replaced almost all long staple cotton which occupies around 88% of total cotton cultivation in Myanmar. Over the recent years, the share of long staple cotton has increased substantially from 75% in 2010 to 88% in 2014. The "Ngwe chi 6" was developed, produced and distributed by the State-owned 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 was used for the first time in 2006-07. Notably the Bt cotton variety

has had a far reaching impact on cotton production and helped Myanmar achieve the doubling of cotton production from 2006 to 2014. As a result, enhanced farm income from biotech crops is provisionally estimated at US$138 million for the period 2006 to 2013 and the benefits for 2013 alone at US$28 million.

In addition to large scale adoption of Bt cotton, Myanmar has been increasing the adoption of high yielding hybrid rice and hybrid maize cultivation in the recent years. It is expected that Myanmar would increase rice paddy production to 19 million tons cultivated over approximately 7 million hectares in 2014. Myanmar also announced a new national export strategy for 2014-2019 aiming at tripling rice exports from 1 million ton in 2014 to 3 million tons in 2019. Similarly, maize production showed an upward trend with an estimated production of 1.75 million tons from 450,000 hectares in 2014. Moreover, the new national export strategy for 2014-2019 aims at boosting the export potential of beans and pulses, mineral products, finished wood products and garments.

MYANMAR

Population: 48.3 million

GDP: US$55.3 billion

GDP per Capita: US$1,132

Agriculture as % GDP: 38.8%

Agricultural GDP: US$21.5 billion

% employed in agriculture: 70%

Arable Land (AL): 10.4 million hectares

Ratio of AL/Population*: 0.8

Major crops:
- Rice
- Cotton
- Sugarcane
- Beans
- Pulses
- Groundnuts
- Sesame

Commercialized Biotech Crop: Bt Cotton

Total area under biotech crops and (%) increase in 2014:
0.318 Million Hectares (+5%)

Increased farm income for 2006-2013: US$138 million

*Ratio: % global arable land / % global population

For the first time, Myanmar chaired ASEAN and hosted 25th ASEAN Summit in 2014 along with the 36th meeting of the Asian Ministers on Agriculture and Forestry (36th AMAF) with an objective to "Moving Forward in Unity to a Peaceful and Prosperous Community". The 36th Agriculture ministers meeting adopted the joint resolution to harmonize regulations and standards in agriculture to achieve food security and zero hunger in the ASEAN region; a goal to which biotech crops can contribute. The key components of the food security arrangements relevant to agriculture R&D, harmonisation of regulation and standards in agriculture were set. The Government is keen to pursue biotech applications that can contribute to food security.

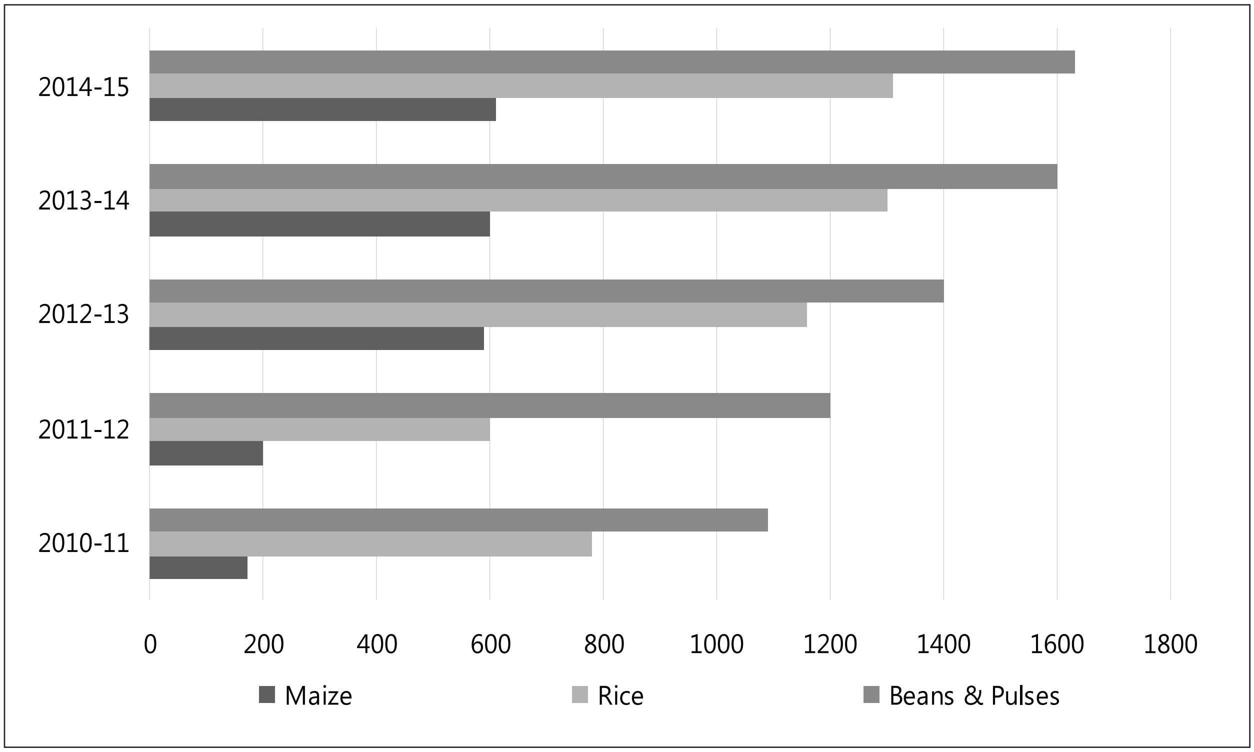
Myanmar: A Hub for Exportable Agriculture Commodity in ASEAN

Myanmar annually exports approximately US$9 billion worth of agricultural products which accounts for more than 16% of total national export earnings. The major exportable agricultural products include rice, beans and pulses, maize and wood based products predominantly sesame and teak wood. Agriculture sector employs a sizeable portion, approximately half of 53 million population. Agriculture contributes more than half (50.3%) of the national Gross Domestic Product (GDP) of US$56 billion or equivalent to US$800-US$1,000 per capita (WTO, 2014). Agriculture 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 12 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 six principal crops – rice, beans and pulses, maize, cotton and sugarcane that ensure food self sufficiency and earn significant foreign exchange.

Figure 25 shows the trend in export of key agriculture commodities in Myanmar from 2010 to 2014. Notably, rice occupies the largest cultivated areas of approximately 7 million hectares followed by beans and pulses at 4.3 million hectares, maize occupies 450,000 hectares and cotton occupies about 350,000 hectares of cultivated area (MCSE, 2001; UNEP GEF, 2006; GAIN, 2014). 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 nine years of its commercial release. The remaining cotton area of approximately 45,000 hectare is being cultivated with two popular non-Bt short staple varieties “Wargyi” and “Mahlaing”. 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, 44 and 46 (James, 2011, 2012 & 2013) provides a detailed overview of agriculture, R&D and cotton crop in Myanmar.

In the nine year period, smallholder farmers in Myanmar rapidly adopted Bt cotton, which occupied approximately 318,000 hectares or 88% of total cotton cultivation in 2014. In addition to the wide scale adoption of Bt cotton, Myanmar has been increasing the adoption of high yielding hybrid rice and hybrid maize cultivation in recent years. It is expected that Myanmar would increase rice paddy production to 19 million tons cultivated over approximately 7 million hectares in 2014. Buoyant by the export potential of key agricultural commodities (Figure 25), Myanmar also announced a new national export strategy for 2014-2019 aiming at tripling rice export from 1 million ton in 2014 to 3 million tons in 2019. In 2014, Myanmar doubled rice export to 1,310,000 tons from 778,000 tons in 2010. Similarly, maize production showed an upward trend with an estimated production of 1.75 million tons harvested from 450,000 hectares in 2014. The export of beans and pulses soared from 1 million tons in 2010 to 1.6 million tons in 2014. Myanmar’s new national export strategy for 2014-2019 aims at accelerating the export potential of rice, beans and pulses, maize, mineral products, finished wood products and garments (FAO, 2014).

Figure 25. Trend in Export of Key Agriculture Commodities in Myanmar, 2010 to 2014 (thousand tons)



Source: Analyzed and Compiled by ISAAA, 2014.

Harmonization of Regulation and Standards in ASEAN

Myanmar is a member of the World Trade Organization (WTO) since 1995 and of the Association of Southeast Asian Nation (ASEAN) in 1997. In 2014, for the first time Myanmar chaired and hosted ASEAN 2014 with an objective to "moving forward in unity to a peaceful and prosperous community". Since 2011, Myanmar has undertaken major political, economic and administrative reforms that strived to play a more active role in the Southeast Asian region (ASEAN, 2014). As a part of ASEAN 2014 chairmanship, Myanmar hosted the 36th meeting of the Asian Ministers on Agriculture and Forestry (36th AMAF) to facilitate agriculture and rural development, facilitate trade, set standards, and enhance policy and food security framework among ASEAN countries.

While opening the 36th AMAF, the President of the Republic of the Union of Myanmar Honorable U Thein Sein emphasised the need to take concerted efforts in addressing food security and nutrition to meet the United Nation's Millennium Development Goals (UN-MDGs). The President urged ASEAN to work together to overcome the adverse impacts of climate change and ensure sustainable agriculture. ***"Double efforts need to be undertaken to conserve natural resources, including water and forest resources, and to protect ecological system as well as to develop smallholder farmers and***

family farming system" stated the President Honorable U Thein Sein. He also called on the ASEAN Community to enhance cooperation and strengthen partnerships with international development partners. The 36th AMAF adopted the joint declaration that focuses on "moving towards 2015 and beyond" and "food security arrangements" and to revise ASEAN Integrated Food Security (AIFS) Framework addressing the twin challenges in the realisation of the common goal of long-term food security and nutrition. It also emphasized the development of a framework to harmonize regulations and standards in agriculture and to achieve "zero hunger" for the remaining 12% of the population in the Asia Pacific region. The key components of the food security arrangements relevant to agriculture R&D, harmonisation of regulation and standards in agriculture include:

- Setting up of ASEAN Agricultural Research and Development Information System (ASEAN-ARDIS)
- Enhancing investment in R&D with a focus on technologies that are greener, more adaptable, more affordable and more suitable for smallholders and innovations that help producers to adapt on the challenges of climate change and dwindling natural resources
- Strengthening ASEAN Genetically Modified Food Testing Network (ASEAN GMF Net), ASEAN Food Safety Network (AFSN) and ASEAN Rapid Alert System for Food and Feed (ARASFF)
- Supporting IRRI's initiative on Global Rice Science Partnership: Securing a Stable Rice Supply by Building a New Generation of ASEAN Rice Scientists will provide the opportunities for the creation of a new generation of ASEAN rice scientists and extension professionals (ASEAN, 2014).

Agriculture & Trade Policy in Myanmar

On the policy and legislative system in agriculture input sector including seeds, there has been a major thrust to liberalize the State's control on procurement, trade and export of agricultural commodities since early nineties. Myanmar ended the centrally planned economic system and adopted the market oriented economic system in 1988-89. The momentum of liberalization took off with the opening of rice trade and export to private sector in 2003. The country placed a substantial emphasis on enacting legislative instruments that promote the supply of agricultural inputs primarily controlled by the Ministry of Agriculture and Irrigation (MOAI). The input sector opened to public/private entities with the enactment of the Pesticide Law in 1990 and made operational by the Formulation of the Pesticide Board in 1992 to regulate the use of pesticides in agriculture. Subsequently, the plant pest quarantine law was enacted and enforced to prevent quarantine pests entering into the country in 1993. The use of fertilizers particularly nitrogen based fertilizers were promoted by enacting the Fertilizer Law in 2002.

In recent years, Myanmar has repealed the Land Nationalization Act of 1953 by enacting the Farmland Law in 2012 that allows the countrymen with 'land use rights' to transfer, exchange, or lease their land. The Farmland Law has come into force, effective 31st August 2012 (President Office, 2012). In the past, Myanmar citizens used to sell their land openly however it was not registered into the legal books of the Government of Myanmar. By enacting and enforcing the Farmland Law 2012, the citizens can legally sell, purchase, transfer, exchange and lease out their property to others. Similarly, the Government of Myanmar introduced a new law the "Virgin and Fallow Land Law" in 2012 to encourage the use of unused virgin and fallow land for increasing the arable area and food production to meet the demand of growing population, which is expected to increase from 59.13 million in 2009-10 to estimated 67.22 million in 2019-2020.

In order to promote the seed sector in the country, the Government of Myanmar has enacted the Seed Law 2011 by the State Peace and Development Council (SPDC) of the Union of Myanmar on 7th January 2011, which came into force on 7th January 2013. The Seed Law 2011 aims to:

- assist the development of agricultural sector of the State by cultivating and producing crops using pure seed;
- enable to carry out the seed business commercially and to carry out such business systematically;
- encourage for enabling participation in seed production and carrying out seed research of the Government departments, organizations and individuals, and
- enable the Government department organizations, international organizations, internal and external organizations and individuals to co-operate for the development of seed business (Shein, 2013).

Notably, the Seed Law 2011 encourages the R&D, production and supply of seeds and plant variety in order to ensure trueness of variety, seed vigor and germination, uniformity and free from foreign material and insects and diseases. The Seed Law obligates the suppliers to ensure the minimum seed quality control such as field inspection, sampling, testing and certification of seeds to be supplied to farmers. The Seed Law 2011 sets up a procedure for registration of new variety of seed that needs to go through a process of 3 seasons of yield trials and 2 seasons of adaptability test followed by farmers' field testing and approval by Technical Sub Committee (TSC) before registration by the National Seed Committee (NSC) in Myanmar. In recent years, the efforts are made by the Department of Agriculture (DOA) to promote the public- private partnership in seed multiplication of OPV and hybrids of rice, corn, cotton and vegetable crops. In particular, the emphasis has been laid to enhance collaboration with private seed companies to increase the availability of quality seeds by involving private companies including CP Seeds Company for hybrid corn, Known You Seeds Company for melon and cucumber, Malar Myaing and other small seeds companies for vegetable seeds, Myat Min Seeds for rice and Bayer CropScience for hybrid rice and others. As of 2013, Myanmar is contemplating to draft the new plant variety protection system to comply with the international obligations of the Agreement of Agriculture (AOA) of the World Trade Organization (WTO) to which Myanmar became a member country in 1995. Table 30 shows the enactment of different legislative system to regulate and promote agriculture inputs including seeds, pesticides and fertilizer in Myanmar.

Recognizing the importance of food security for a growing population, The Vice-President of the Union of Myanmar Mr. U Nyan Tun emphasized the formulation of the national action plan for food security and nutrition for the country. ***"There is a need to provide the daily food requirement as well as the availability of wholesome food for all the citizens in order to be healthy and secure the longer life span as present world population of seven billion is estimated to be more than nine billion by 2050,"*** said the Vice-President while inaugurating the ceremony of the World Food Day on 16th October 2013. He further highlighted the role of the green economy in order to attain sustainable food security without negative environmental consequences. ***"The Government is obliged to work out for food security of ever increasing population of present 60 million people***

Table 30. Legislative System to Regulate & Promote Agriculture Inputs by the MOAI in Myanmar, 2014

Legislative system	Scope of activities	Status
The Biosafety Law	To regulate GM crops	Draft prepared, Pending Enactment
The Seed Law	To maintain quality and supply of seeds	Enacted on 7th January 2011 Enforced on 7th January 2013
The Farmland Law	To allow a person with 'land use rights' to transfer, exchange, or lease his/her land	Enacted on 2012 Enforced on 31st August 2013
The Virgin and Fallow Land Law	To promote the use of unused land	Enacted on 2012
The Fertilizer Law	To manage the use of fertilizers	Enacted and enforced on 1st December 2002
The Plant Pest Quarantine Law	To prevent quarantine pests entering into the country	Enacted and enforced in 1993
Formulation of the Pesticide Board	To regulate the use of pesticides	Enforced on 25th February 1992
The Pesticide Law	To regulate the use of pesticides	Enacted on 11th May 1990

Source: Shein, 2013; Shein & Myint, 2013; Aung and Thet, 2009; Compiled by ISAAA, 2014.

which is expected to be 100 million by 2050 in one hand, while it is dealing with the issues of negative impacts of climate change and disasters on agriculture sector," he added (President Office, 2013).

"Ngwe chi 6" Bt Cotton in Myanmar

In 2010, for the first time, Bt cotton was reported to be 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, 300,000 hectares in 2012, 305,000 hectares in 2013-14 and 318,000 hectares in 2014-15. Bt cotton was farmed by 454,000 farmers in 2014-15 compared to 435,000 in 2013-14, 428,000 farmers in 2012-13, 375,000 in 2010-11 with increasing adoption of 75% in 2010-11 to 84% in 2012-13, to 85% in 2013-14 and 88% in 2014. The insect resistant Bt cotton now occupies the entire long staple cotton hectarage in the country (Table 31).

Table 31. Adoption of Bt Cotton in Myanmar, 2006 to 2014

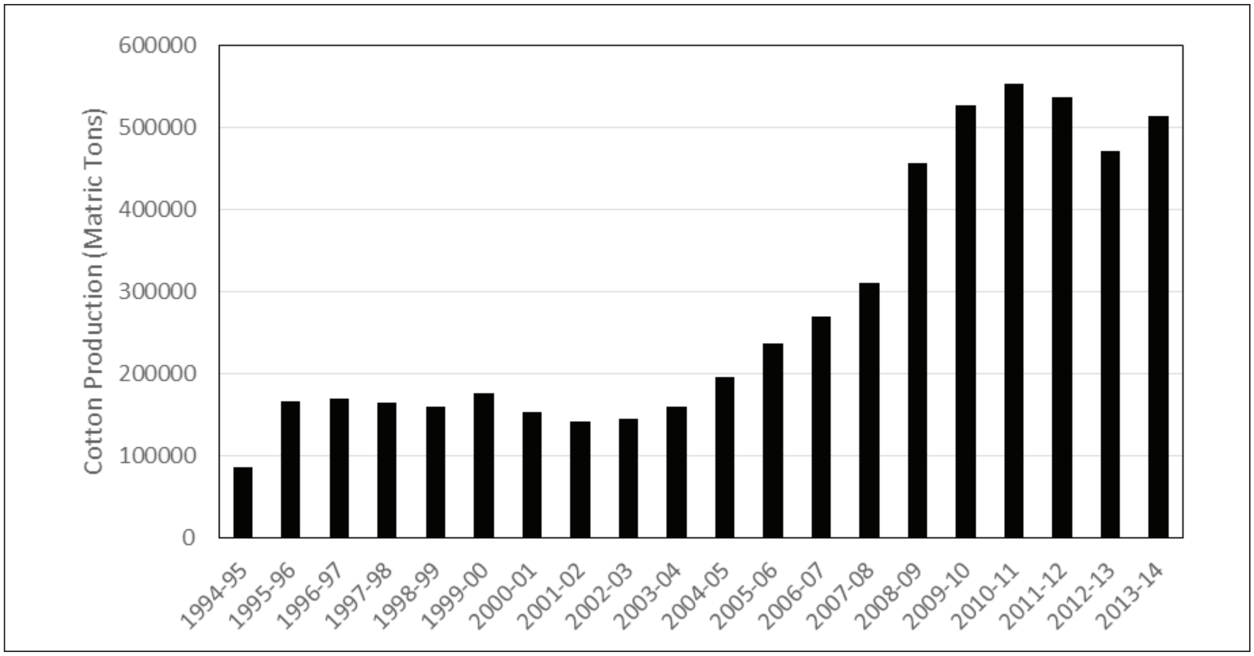
Year	Adoption of Bt Cotton (ha)	Total Cotton (ha)	% Adoption
2006-07	<500	300,000	<1%
2007-08	8,300	368,000	2%
2008-09	140,000	360,000	39%
2009-10	270,000	360,000	75%
2010-11	270,000	360,000	75%
2011-12	283,000	358,000	79%
2012-13	300,000	359,000	84%
2013-14	305,000	360,000	85%
2014-15	318,000	360,000	88%

Source: Analyzed and compiled by ISAAA, 2014.

In 2014-15, approximately 42,000 hectares of cotton area were planted with short staple non-Bt cotton varieties Wargyi" and "Mahlaing", for which Bt cotton varieties are not available. "Ngwe chi 6" is the only long staple Bt cotton variety released to date in Myanmar. According to the Ministry of Agriculture's Extension Department, approximately 88% of the cotton grown in Myanmar is long staple cotton whilst the balance of 12% is short staple. The short staple cotton is inter-cropped with cotton-pigeon pea in the country. 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 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.

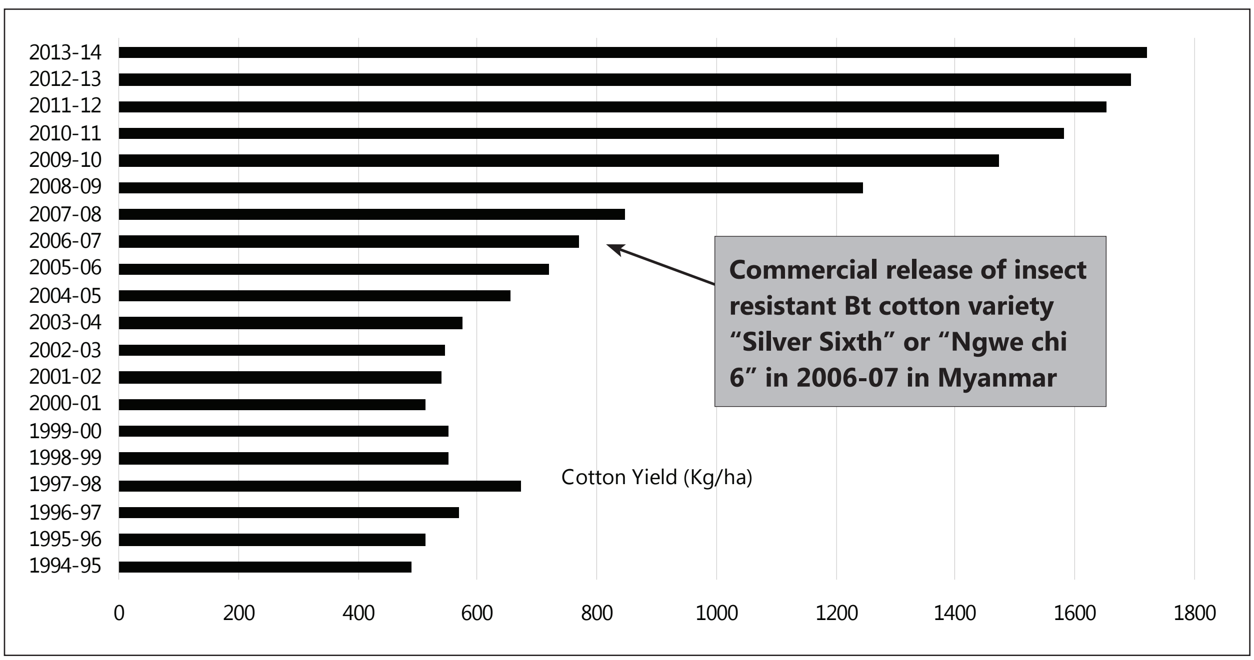
In 2009, Myanmar grew 360,000 hectares of cotton of which 270,000 hectares were long staple cotton producing 524,000 MT or 93 percent of total cotton production, whilst 68,000 hectares were short staple cotton producing only 38,000 MT or 7% of total cotton production (Figure 26). The yield of short staple 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 and 1,719 kg per hectare in 2013-14, 125% increase in cotton yield in a short period of seven years as shown in Figure 27 (MICDE, 2012b and MICDE, 2014). 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

Figure 26. Cotton Production in Myanmar, 1994-95 to 2013-14



Source: MICDE, 2012b and 2014; Nu, 2011; Analyzed and compiled by ISAAA, 2014

Figure 27. Cotton Yield in Myanmar, 1994-95 to 2013-14



Source: MICDE, 2012b and 2014; Nu, 2011; Analyzed and compiled by ISAAA, 2014

Myanmar. Similarly, cotton production more than doubled from 271,069 MT in 2006-07 to 514,689 MT in 2013-14 (Figure 26). 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.

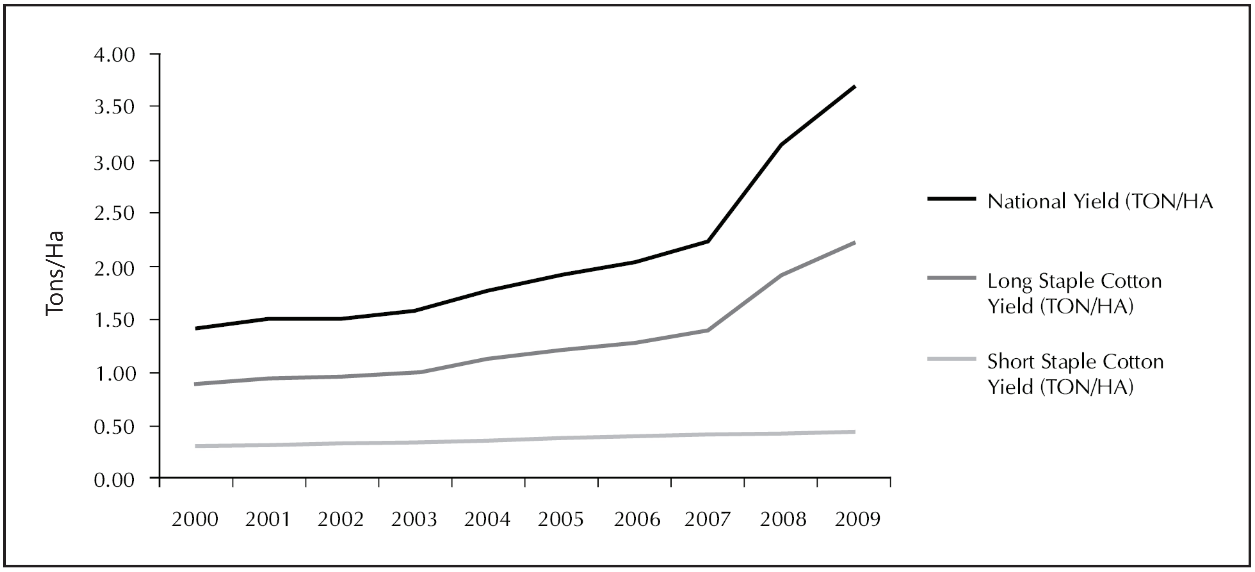
While addressing Myanmar's Union Minister of Agriculture and Irrigation, H.E. U Myint Hlaing recognized the contribution of Bt cotton variety "Ngwe Chi-6" to national cotton production during the Agriculture Seminar on the Global Review of Commercialization of Biotech/GM Crop: 2013, organized jointly by the Minister of Agriculture and Irrigation (MOAI), the National Economic and Social Advisory Council (NESAC) and ISAAA on 24 February 2014 at Nay Pyi Taw, Myanmar. Union Agriculture Minister Myint Hlaing elaborated on the development and adoption of Bt cotton in Myanmar and stated that ***"as for GM crop cultivation, a long staple cotton variety named Silver-6 popularly known as Ngwe Chi-6 Bt cotton released in 2006-2007 in Myanmar after following the field trial at cotton research farm. Cotton farmers in Myanmar have quickly adapted and switched to Ngwe-Chi-6 Bt cotton varieties within short duration of 2006 to 2013. The use of Bt cotton has resulted in significant benefit for the farmers such as higher crop yield, reduced input costs, increased profit and less hazard export to pesticides. Although the potential benefits of Bt cotton are large in the country, the scientific capacity to maintain the generation and to access the biosafety of GM crops is still needed. In addition, the evaluation on their work, regulatory capacity for safe deployment and legal system need to be strengthened"*** (MOAI, 2014).

Benefits of Bt Cotton

Compared to conventional long staple cotton, the best Bt cotton growers are estimated to have increased cotton yield by 125% in a short period of seven years from 2006-07 to 2012-13, more than doubling of yield using "Ngwe chi 6" which requires one third less insecticides, resulting in a net significant increase in income (GAIN, USDA/FAS, 2010). At national level, cotton production has more than doubled from 271,069 MT in 2006-07 to 618,220 MT in 2012-13. 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 28). In 2012-13, it was estimated that the long staple cotton yield increased to 2,100 kg per hectare as compared to the yield of 450 kg per hectare for short staple cotton, four times the yield difference between short staple cotton and long staple cotton grown in Myanmar.

Provisional estimate indicate that enhanced farm income from biotech crops is estimated at US$293 million for the period 2006 to 2013 and the benefits for 2013 alone at US$28 million (Brookes and Barfoot, 2015, Forthcoming).

Figure 28. Comparing Yield of Long Staple Bt Cotton, Short Staple Cotton and National Average, 2000 to 2009



Source: Adopted from GAIN, USDA FAS, 2010.

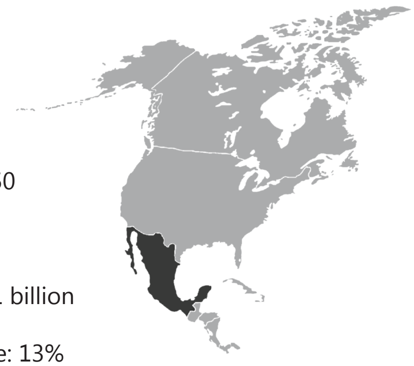
MEXICO

In 2014, Mexico planted 170,000 hectares of biotech crops (up 64,000 from 2013) and comprised 160,000 hectares of biotech cotton and 10,000 biotech maize. Of the 160,000 hectares of cotton 154,000 hectares are stacked and 6,000 hectares are HT, and in total equivalent to a 94% adoption. The hope is that Mexico will adopt a national, science-based, strategy that will allow the centers of origin of maize to be protected as well as ensuring that Mexico will benefit from biotech maize which can contribute to national food security and mitigate the new challenges, like more frequent and severe droughts, associated with climate change. Mexico cultivates about 7 million hectares of maize and is heavily dependent on ~10 million tons of maize imports valued at about US$2.75 billion annually. Mexico is provisionally estimated to have enhanced farm income from biotech cotton and soybean by US$293 million in the period 1996 to 2013 and the benefits for 2013 alone is US$55 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 2014, Mexico planted 160,000 hectares of biotech cotton, at an adoption rate of 94% of a total 170,000 total cotton hectarage, and equivalent to a 40% increase from 2013's 114,000 hectares. It is comprised of 6,000 herbicide tolerant and 154,000 hectares stacked products (equivalent to ~90.5% of the 160,000 hectares biotech cotton hectarage). The major reason for the increase was fewer droughts than 2013. Data in Table 32 shows that 90.5% of all cotton was planted to the stacked gene HT/IR product favored by farmers, 3.5% as HT and the balance of 6% as conventional.

Mexico planned to be self sufficient in cotton. This was evident in its 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. Henceforth, approval was 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. However, due to drought and low cotton prices, the plan did not materialize.

MEXICO



Population: 114.8 million

GDP: US$1,153 billion

GDP per Capita: US$10.050

Agriculture as % GDP: 4%

Agricultural GDP: US$46.1 billion

% employed in agriculture: 13%

Arable Land (AL): 25.6 million hectares

Ratio of AL/Population*: 1.0

Major crops:
- Maize
- Wheat
- Soybeans
- Rice
- Cotton
- Coffee

Commercialized Biotech Crops:
- Bt Cotton
- HT Soybean

Total area under biotech crops and (%) increase in 2014:
0.170 Million Hectares (+49%)

Farm income gain from biotech, 1996-2013: US$293 million

*Ratio: % global arable land / % global population

Biotech Maize

Experimental field trials were conducted in the past in the northern states of Mexico: Sonora, Sinaloa, Tamaulipas, Chihuahua and Coahuila which proved the effectiveness of maize biotech traits. Additional approvals were also granted for field evaluations under the aegis of the Pilot phase project (pre-commercial) in Sinaloa and Tamaulipas. 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 is 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 cultivates about 7 million hectares of maize and is heavily dependent on about 10 million tons

Table 32. Biotech Cotton in Mexico, 2014

Trait	Total Hectares for 2014	% Biotech cotton
Bt/HT	154,000	90.5%
HT	6,000	3.5%
Conventional	10,000	6.0%
TOTAL	**170,000**	**100.0%**

Source: Compiled by Clive James, 2014.

of maize imports valued at about US$2.75 billion 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.

AgroBIO Mexico and its partners have stated that they will continue to be respectful of the institutions and decisions made by administrative and judicial authorities in Mexico. AgroBIO Mexico and the plant science industry is convinced of the need to continue GM maize field trials and pilot planting programs, as they enable the generation of information and data needed for government authorities to scientifically evaluate applications from private and public sector researchers. Furthermore, the plant science industry in Mexico is of the view that the eventual commercial plantings of biotech maize will be a significant milestone for Mexico, after an 11 year moratorium. AgroBIO Mexico opines that the country must avoid a new moratorium, or farmers will be denied the right to choose innovations which allow them to be more productive and competitive.

The hope is that Mexico will adopt a plan that will allow the centers of origin of maize to be protected as well as benefiting from biotechnological advancements which can contribute to food security, and mitigate the new challenges, like more frequent and severe droughts, associated with climate change.

Benefits from Biotech Crops in Mexico

Provisionally, Mexico is estimated to have enhanced farm income from biotech cotton and soybean by US$293 million in the period 1996 to 2013 and the benefits for 2013 alone is estimated at US$55 million (Brookes and Barfoot, 2015, Forthcoming).

SPAIN

> **Spain is the lead biotech crop country in Europe, and grew 131,538 hectares of Bt maize in 2014; this compares with 136,962 in 2013. The marginal decrease of 4% is due to less total maize plantings of approximately 28,000 hectares in 2014 but the adoption rate in Spain was marginally up at 31.6% in 2014 compared with 31% in 2013. Spain has successfully grown Bt maize for sixteen years, and grew 92% of the Bt maize in Europe in 2014. Total plantings of maize in Spain was 6% less in 2014 at 416,690 hectares compared with 444,473 hectares in 2013, which in turn decreased biotech maize hectarage. Enhanced farm income from biotech Bt maize is provisionally estimated at US$206 million for the period 1998 to 2013 and for 2013 alone at US$29 million.**

Spain is the only country in the European Union to grow a substantial area of a biotech crop. In 2014, Spain grew 92% of all the 143,474 hectares of biotech maize in the EU. Note that the 2014 estimates by the Government of Spain include, Bt maize hybrids approved in other EU countries. Spain has successfully grown Bt maize for sixteen 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 19 biotech mega-countries globally growing 50,000 hectares or more of biotech crops. In 2014, the Bt maize area in Spain reached 131,538 hectares compared with 136,962 hectares in 2013. The adoption rate in 2014 was a record 31.6% a slight increase from 2013's 31%. In 2014, total maize plantings at 416,690 hectares were 6% less than in 2013 at 444,473 which in turn decreased biotech maize planting. The principal areas of Bt maize in Spain in 2014 were in the provinces of Aragon (54,040 hectares) where the adoption rate for Bt maize was 68% compared with 73% in 2013, followed by Cataluña (36,381) with the highest adoption rate of 87% for 2014, compared with 82% last year, and in Extremadura (13,815), with an adoption rate of 22%; the balance of Bt maize was grown in eight other provinces in Spain in 2014 (Tables 33 and 34).

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 2013. 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.

SPAIN

Population: 46.5 million

GDP: US$1,477 billion

GDP per Capita: US$31,990

Agriculture as % GDP: 3.0%

Agricultural GDP: US$42.21 billion

% employed in agriculture: 4%

Arable Land (AL): 12.7 million hectares

Ratio of AL/Population*: 1.3

Major crops:
- Grape
- Maize
- Wheat
- Sugar beet
- Potato

Commercialized Biotech Crops: Bt maize

Total area under biotech crops and (%) increase in 2014:
0.132 Million Hectares (-418%)

Farm income gain from biotech, 1998-2013: US$206 million

*Ratio: % global arable land / % global population

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 new traits 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 indicated 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 approved for the EU (Crop Biotech Update, 20 January 2012).

Table 33. Hectares of Biotech Bt Maize in the Autonomous Communities of Spain, 1998 to 2014

Provinces	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
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	54,451	54,040
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	33,996	36,381
Extremad-ura	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	16,979	13,815
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	14,079	10,692
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	8,766	7,973
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	7,013	7,264
Valencia	190	300	150	100	20	72	73	293	0	0	14	0	23	107	522	913	640
Madrid	660	1,560	1,970	1,940	780	1,034	1,385	155	80	193	381	130	340	418	421	531	520
Islas Baleares	2	2	26	0	30	6	29	29	0	3	3	92	75	52	154	174	160
Castilla Y Leon	200	360	270	0	0	74	0	12	0	13	28	19	0	6	8	6	18
Murcia	0	0	0	0	0	0	12	0	0	24	0	0	0	0	4	52	24
La Rioja	25	30	30	0	0	0	35	41	122	4	11	8	5	21	0	2	9.4
Cantabria	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	0	0
Asturias	0	0	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**	**136,962**	**131,538**

Source: Ministry of Environment Rural Development and Fisheries, Spain, 2014. Avances Suopefices y Producciones Agricolas, September 2014.

Table 34. Total Hectares of Maize Planted and Percentage Adoption of Bt Maize in Spain by Province, 2014

Province	Total Hectares (2014)	Percent Bt Adoption (2014)
Castilla y Leon	118,266	1
Aragon	78,891	68
Extremadura	61,950	22
Castilla-Mancha	34,215	23
Andalucia	32,604	33
Catalunia	41,905	87
Galicia	19,261	0
Navarra	18,988	38
Madrid	7,250	7
Canarias	747	0
La Rioja	680	1
Pais Vasco	395	0
C. Valenciana	773	83
Cantabria	133	0
Balearas	232	69
Pais de Asturias	250	0
R de Murcia	150	2
Total	**416,690**	**31.6%**

* Provisional data pending confirmation
Source: Ministry of Environment Rural Development and Fisheries, Spain, 2014. Avances Suopefices y Producciones Agricolas, September 2014

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 environment-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 provisionally estimated to have enhanced farm income from biotech Bt maize by US$206 million in the period 1998 to 2013 and the benefits for 2013 alone is estimated at US$29 million (Brookes and Barfoot, 2015, 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

Jose Luis Romeo, a fourth generation family farmer in Ebro Valley of northern Spain expressed his views on biotech crops in an editorial at Truth about Trade.

"Where I live...we have a serious problem with the European corn borer. This pest drills into corn stalks, making them weak and barely able to stand. When the wind blows, it knocks down the corn. And the wind can blow so hard here that we have a special name for it: "the cierzo". When corn lies on the ground, of course, it is impossible to harvest. GM corn, however, carries a natural resistance to the corn borer and we don't have to spray our fields with insecticide. The bugs leave it alone. So when the cierzo strikes, our corn stands tall. Best of all, we are obtaining better yields. Biotechnology lets me raise two crops per year. Right now, I'm planting barley and peas. I'll harvest them in June and then replant my fields with corn, without tillage. Corn that starts in June doesn't have as much time to grow, so its stalks are thinner and more vulnerable to corn borers and high winds. When I plant crops that are genetically modified, however, they grow strong and we can harvest two crops rather than just one. We're doing more with less. Food is more affordable. So biotechnology contributes to the spread of sustainable agriculture—environmentally and economically sustainable agriculture. My only regret about biotechnology is that we don't have more of it. Although we grow corn that can defeat the corn borer, the European Union won't let us have access to varieties of biotechnology that would help our crops to beat other threats, including weeds, rootworm, and drought" (Truth about Trade and Technology, 13 April 2014).

COLOMBIA

In 2014, Colombia grew 18,000 hectares of biotech cotton and 81,000 hectares of biotech maize for a total of 99,000 hectares, compared with 109,000 hectares in 2013. The decrease in biotech maize planting was 5% compared to 85,000 in 2013. Around 56% of biotech maize is the stacked trait, 34% Bt and 10% HT. In 2014, 96% of the biotech cotton was the stacked product Bt/HT. Colombia is provisionally estimated to have enhanced farm income from biotech cotton by US$103 million in the period 2002 to 2013 and the benefits for 2013 alone is estimated at US$22 million.

In 2014, Colombia grew 18,000 hectares of biotech cotton and 81,000 hectares of biotech maize for a total of 99,000 hectares, compared with 109,000 hectares in 2013. Biotech cotton has been grown for 11 years. Biotech maize was previously grown under a pre-commercial project "controlled planting program" in two regions, one on the Coast and Llanos region and the other in the interior of the country. Colombia grew 81,000 hectares of biotech maize in 2014 compared with 85,000 hectares in 2013. Of the 81,000, 56% (45,000 hectares) were the stacked traits Bt and herbicide tolerance (Bt/HT), ~28,000 hectares were Bt (34%) and the balance of about 10% was herbicide tolerant. The 18,000 hectares of biotech cotton is approximately 90% stacked product.

Colombia has approximately 600,000 hectares of maize which is benefiting from the technology. Colombia has been growing blue biotech carnation for export only since 2002, and in 2014 planted an estimated 4 hectares in greenhouses.

COLOMBIA

Population: 46.9 million

GDP: US$333 billion

GDP per Capita: US$7,100

Agriculture as % GDP: 7%

Agricultural GDP: US$23.3 billion

% employed in agriculture: 18%

Arable Land (AL): 1.8 million hectares

Ratio of AL/Population*: 1.0

Major crops:
- Coffee
- Maize
- Cotton
- Bananas
- Rice
- Sugarcane

Commercialized Biotech Crops:
- Bt Maize
- Bt Cotton

Total area under biotech crops and (%) increase in 2014:
0.109 Million Hectares (-9%)

Farm income gain from biotech, 2002-2013: US$103 million

*Ratio: % global arable land / % global population

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 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$103 million in the period 2002 to 2013 and the benefits for 2013 alone is estimated at US$22 million (Brookes and Barfoot, 2015, Forthcoming).

Farmer Testimonies

Sergio Valencia of Llanos Orientales (Eastern Plains), Colombia has farmed corn, soybeans, coffee, citrus, tomatoes, passion fruit, banana, and African palm, 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 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).

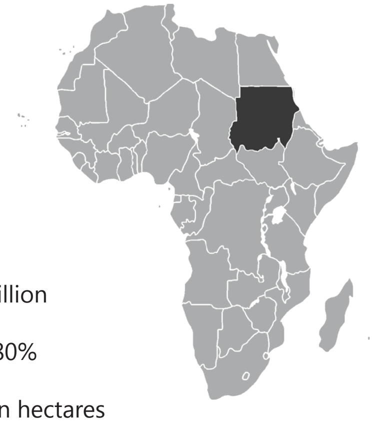
SUDAN

2014, was the third year of commercial planting of Bt cotton in Sudan. A total of 90,000 hectares up from 61,530 hectares, a 46% increase from 2013 were planted in both rainfed and irrigated areas. Close to 30,000 farmers planted Bt cotton compared with the initial 10,000 beneficiaries who have an average of about 1 to 2.5 hectares of land. Of the 109,200 total cotton hectarage, 80% was biotech. 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. In the first year of commercialization, Bt cotton saved 37% of the direct cost of cotton production: the cost of producing non Bt cotton was much higher at US$372 for one feddan (0.42 hectares) compared with US$246 for Bt cotton. The net profit for a farmer planting Bt cotton was US$170 per feddan (equivalent to US$410 per hectare). The Ministry of Agriculture has embarked on an extensive tracking of the socio-economic impacts as more farmers engage in planting 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, and Libya. 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 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 South to 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 year 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 staple food crop. Other important staple crops are wheat and millet. Cash crops for domestic consumption and export includes peanuts and sesame.

Sudan has a long history of cultivating extra-long staple cottons, but the variety spectrum has broadened to include long, medium and short staple varieties. 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.

SUDAN



Population: 33.6 million

GDP: US$64.1 billion

GDP per Capita: US$2,330

Agriculture as % GDP: 33%

Agricultural GDP: US$21.1 billion

% employed in agriculture: 80%

Arable Land (AL): 17.1 million hectares

Ratio of AL/Population*: 2.0

Major crops:

- Cotton
- Sugarcane
- Sorghum
- Wheat
- Cassava
- Millet

Commercialized Biotech Crop: Bt Cotton

Total area under biotech crops and (%) increase in 2014:
0.090 Million Hectares (+46%)

*Ratio: % global arable land / % global population

2014, was the third year of commercial planting of Bt cotton in Sudan. A total of 90,000 hectares up from 61,530 hectares in 2013 were planted in both rainfed and irrigated areas by close to 30,000 farmers, a three-fold increase from the initial 10,000 beneficiaries. The total hectarage of Bt cotton of 90,000 was distributed in six of the major irrigated areas: Gezira, Rahad, New Halfa, Suki, Sennar and White Nile; and in the rainfed areas of Blue Nile State, North Kurdufan and, Arab Company Sudan and Egyptian Company under large scale mechanized production system. The adoption rate of 80% is equivalent to 90,000 hectares.

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. Notably, Bt cotton saved 37% of the direct cost of cotton production while the cost of producing non Bt cotton was much higher at US$372 for one feddan compared with US$246 for Bt cotton. The net profit for a farmer planting Bt cotton was US$170 per feddan (equivalent to US$410 per hectare).

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 was 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. Experiences from the 3rd season crop reinforces the importance of good farm management, timely availability of seeds and inputs as well as sustained communication with stakeholders to address misinformation. Expanding the area under Bt cotton will thus require an agronomic package supported by an efficient extension service and coordinated awareness and outreach strategies.

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. However, in absolute terms, domestic lint consumption consistently declined from an average of 86,000 bales during the 1980s to only 16,000 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 industry. The Bt cotton program is one such effort that responds to a real need and is poised to position Sudan back on the global map as a major player in the world cotton trade.

The major outcomes from the three seasons of planting Bt cotton in Sudan were: Bt cotton adoption should continue due to its endogenous control of boll worms. This was reflected in reduction in production cost, increase in cotton productivity and maintaining the environmental balance. Reduction in the damage by the sucking insects and improvement of cotton quality by reducing stickiness were also observed.

Cotton farming in Sudan is mainly conducted by male farmers and involves planting, irrigation and picking. Women's contribution is mainly in hand weeding, fertilizer application and hand picking. However except for cotton picking, the other practices are now almost mechanized. Sudanese farmers are already reaping benefits as witnessed by the many testimonies they are easily providing.

Farmer Voices

For many farmers, Bt cotton growing is a real life-changer. Bt cotton farmers were interviewed on site and below are some outstanding comments:

Farmer 1: ***"I expected more than 20 'quntars' of cotton. Before the GM cotton I hardly obtained more than 4 quntars per feddan. This is the first time I do not see immature bolls on the ground."***

Farmer 2: ***"This technology is ours and we will fight for it. Not having to spray so many times is the biggest achievement. Some people said that we have to spray for the worms but we insisted not to do so. The crop is healthy and we expect high returns since we have already saved some money from less spraying."***

Farmer 3: ***"I have planted cotton all my life. Some seasons are good and others are bad. But I didn't see cotton like this. It carries bolls from the base of the stem. This season I will be able to go to Mecca. Thanks my sons."***

HONDURAS

Honduras grew 29,000 hectares of biotech maize in 2014 compared with 20,000 hectares in 2013, an increase of 45%. This comprises 28,000 hectares stacked products and 1,000 hectares of HT maize. Provisionally, Honduras is estimated to have enhanced farm income from biotech maize by US$9 million in the period 2002 to 2013 and the benefits for 2013 alone is US$2 million.

Honduras is a relatively poor country in Central America with a GDP per capita of US$2,290 – 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 weeds and 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 2013, 20,000 hectares of biotech maize was planted, but was surpassed in 2014 by planting 29,000 hectares. Biotech maize in 2014 is comprised of 28,000 hectares of Bt/HT maize and 1,000 hectares of HT maize.

Benefits from Biotech Maize in Honduras

Assuming a modest gain of US$75 per hectare from stacked biotech maize, the national benefit from 28,000 hectares would be about US$2 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.

It is estimated provisionally that Honduras has enhanced farm income from biotech maize by US$9 million in the period 2002 to 2013 and the benefits for 2013 alone is US$2 million (Brookes and Barfoot, 2015. Forthcoming).

CHILE

In 2014, Chile grew 10,000 hectares of biotech maize, canola and soybean, exclusively for seed exports – this compares with 24,000 in 2013 and 62,300 hectares in 2012. Hectarage changes annually and is based on relative net demand for Chile compared to other seed producing countries.

In 2014, Chile was projected to plant 7,000 hectares of biotech maize, 2,000 hectares of biotech canola and 1,000 hectares of biotech soybean for a total of 10,000 hectares for seed export.

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.

From a biotech crop standpoint, it is important to recognize that Chile is the sixth largest producer of export seed in the world in 2012, with a value of US$388 million (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 similar to the other 27 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 20,000 hectares in 2013/14, but was reduced to 7,000 hectares in 2014; the hectarage for biotech canola was 2,000 hectares and 1,000 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.

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

Table 34. Hectares of Major Biotech Seed Crops Grown for Export in Chile, 2002/03 to 2013/14*

Crop	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15
Maize	10,400	8,450	7,614	12,120	17,981	25,000	30,000	28,000	9,378	25,000	45,000	20,000	7,0000
Canola	110	140	746	628	444	2,500	4,200	1,200	3,500	15,000	15,000	3,000	2,0000
Soybean	215	128	273	166	250	500	1,800	3,000	3,800	2,300	2,300	1,000	1,0000
Total	**10,725**	**8,718**	**8,633**	**12,914**	**18,675**	**28,000**	**36,000**	**32,200**	**16,678**	**42,300**	**62,300**	**24,000**	**10,0000**

Source: Government of Chile statistics, SAG, 2014. *industry estimates

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.

PORTUGAL

> **In 2014, Portugal planted 8,542 hectares of Bt insect tolerant maize – a ~5% increase compared to the 8,171 hectares in 2013. In 2014, the 8,542 hectares of Bt maize were grown in 5 regions by 237 Portuguese farmers. Portugal first grew Bt maize in 1999, resumed successful planting in 2005, and since then, they have elected to continue to plant Bt maize for ten years due to 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 2014, Portugal planted 9,000 hectares of Bt maize, which was a Government estimate when this Brief went to Press. The 8,542 hectares compares with 8,171 hectares in 2013, an ~5% increase. The major five 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 8,542 hectares in 2014.

Table 36. Major Regions Planting Bt Maize in Portugal, 2014

Region	Hectares	Percentage of National Bt Maize Hectares
Alentejo	5,457	64
Lisbon/de Tejo	2,074	24
Central	933	11
North	78	1
National	**8,542**	**100**

Source: Ministry of Agriculture, Rural Development, and Fisheries, Lisbon, Portugal, www.dgadr.pt, September, 2014.

The total hectarage of maize plantings in Portugal in 2014 was maize for grain 92,514 hectares, maize for silage 44,144 hectares for 136,644 total hectares. The region of Alentejo had the largest hectarage of Bt maize at 5,457 hectares or 64% of the national hectarage. Alentejo was followed by the Lisbon and Tejo Valley regions with 2,074 hectares of Bt maize or 24% of the national hectarage. The central region was the third region with 933 hectares of Bt maize or 11% of the national hectarage. Norte area was the fourth region with 78 hectares of Bt maize, 1% of the national hectarage of biotech maize. 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."***

CUBA

In 2014, Cuba planted 3,000 hectares of biotech maize similar to the hectarage in 2013 and 2012. Prior to expanding biotech maize hectarage, Cuba has assigned priority to establishing an effective hybrid maize program. Biotech maize is currently planted in a "regulated commercialization" initiative, in which selected farmers seek permission to grow biotech maize commercially. The initiative is part of an "ecologically sustainable pesticide-free program" featuring biotech maize hybrids and mycorrhizal additives. Expansion of biotech maize hectarage is anticipated subsequent to the establishment of an effective hybrid maize program to meet demands at the farmer level. Progress with Bt maize in Cuba is encouraging. The product with resistance to the major pest, fall armyworm, was developed by the Havana-based Institute for Genetic Engineering and Biotechnology (CIGB). Extensive field tests in Cuba 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. This depends on the severity of the armyworm infestation, which varies significantly with climatic and ecological conditions.

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 2014, the regulated commercialization program featured hybrid Bt maize covered up to 3,000 hectares, similar to 2013 and 2012. 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 was included since 2012 in the group of countries that were cultivating biotech crops.

The Bt maize being developed by Cuba is similar to that grown on over 50 million hectares in 16 countries. 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

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 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.

CZECH REPUBLIC

> **In 2014, the Czech Republic grew 1,754 hectares, a ~30% decrease from the 2,560 hectares of Bt maize planted in 2013. This decrease is entirely 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 2014, the Czech Republic grew 1,754 hectares of biotech maize, a minimal decrease from the 2,560 hectares of Bt maize in 2013. The decrease is entirely due to the onerous disincentives for farmers who are required to report intended biotech plantings to government authorities inconveniently early which makes planting almost impractical. 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 as a result 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; there is less incentive for farmers to grow biotech maize for silage because losses due to borer are lower compared to maize for grain. 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.

ROMANIA

Romania planted 771 hectares of Bt maize in 2014, an increase of 550 hectares equivalent to a 350% increase on a small hectarage of 220 hectares in 2013. Romania grew its first 350 hectares of Bt maize in 2007 which increased to a significant 7,146 hectares in 2008. Following the severe economic recession (which severely restricted farmer access to credit), the biotech maize area in 2009 declined to 3,243 hectares, 822 hectares in 2010, 588 hectares in 2011, 217 hectares in 2012, 220 hectares in 2013, and finally a modest increase of 771 hectares in 2014. The hectarage in Romania is likely to remain in the current range. There are several factors involved in a sustained low hectarage in 2014; of particular concern is the onerous and bureaucratic reporting requirements for farmers regarding intended planting details – in some years this is exacerbated by a limited supply of biotech Bt maize seed, as seed suppliers understandably assign lower priorities in a social environment that is hostile to biotech crops and provides no incentives to farmers who are keen to benefit from the technology.

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% less) 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 1999-2006 after which it had to discontinue planting when Romania became an EU member state.

Despite the EU legal requirement for Romania to discontinue the cultivation of RR®soybean, it has been able to take advantage of the fact that Bt maize is registered for commercialized planting in the EU. Romania grew its first 350 hectares of Bt maize in 2007, and this increased more than 20-fold in 2008 to 7,146 hectares. This was the highest percent increase for any country in 2008, acknowledging that the base hectarage of 350 hectares in 2007 was very low. Following the severe economic recession particularly restricted access to credit, the biotech maize area in 2009 declined to 3,243 hectares, 822 hectares in 2010, 588 hectares in 2011, 217 hectares in 2012, a marginal 220 hectares in 2013 and an increase to 771 hectares in 2014. There were several factors involved in the relatively low hectarage such as; an EU stimulated hostile social environment to acceptance of biotech crops; onerous reporting requirements for farmers regarding intended planting details; a limited and decreasing supply of biotech Bt maize seed in a country where understandably seed suppliers assign low priority to the country in the absence of incentives.

It is noteworthy that there are 4.5 million small farms in Romania, which remarkably represent almost a third of all farms in the EU (The Economist, 2007).

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 1999 when it planted 15,500 hectares of RR®soybean of its national soybean hectarage of approximately 100,000 hectares – a 15.5% 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. Brookes (2005) found that as farmers were able to clean up the weeds from fields in early years of adoption, yield gains were graduated from 31% in 2003, 25% in 2004, 19% in 2005 and 13% in 2006. To be able to deliver a yield gain of 13% in 2006 is still a credit to the effectiveness of the technology to control weeds (Brookes, 2005). 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 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 in 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 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 – an example of a negative impact from a flawed logic arising from a bureaucratic requirement. 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 1999, 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 1999 and occupying 145,000 hectares in 2006, the yield benefits of as high as 31% in 2003 was unique – in all other countries, RR®soybean is a yield neutral technology. A study by Brookes (2005) estimated that yield gain in 2003 was 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, respectively. The high yield increases in Romania in 2003 of 31% gradually decreased as farmers fields are cleaned up to reach 13% in 2006, reflecting past low usage of herbicides and ineffective weed management, particularly of Johnson grass, which is very difficult to control.

Estimates by Brookes and Barfoot (2007) showed that Romania had an enhanced farm income from RR®soybean of ~US$45 million in the period 1999 to 2006.

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 2014, the hectarage of Bt maize in Slovakia was 411 compared with 100 hectares in 2013. The increase of 311 hectares is equivalent to a 300% increase but this is on a small hectarage. 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. 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. The Bt maize hectarage in Slovakia is likely to remain low and is entirely due to the requirement of laborious and onerous reporting which are an administrative chore and a compelling disincentive for farmers seeking to plant Bt maize.**

Slovakia grew its first commercial biotech crop, Bt maize in 2006 when 30 hectares 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 2014, the hectarage of biotech maize was 411 hectares compared with 100 hectares in 2013. The hectarage could have been much higher if it were not for the government requirement for laborious reporting which is a significant disincentive for farmers seeking to plant Bt maize for the benefits it offers.

As an EU member state, Slovakia can grow maize with the MON810 event which has been approved by the EU for all of its 28 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.

Slovakia maintains a scientific approach towards biotechnology and considers the use biotech crops to increase agricultural productivity and sustainability. The Slovak Ministry of Agriculture strictly regulates the use of biotechnology; nonetheless its scientific approach has supported the use of BT corn for biogas production and animal feed, eliminating the need for commercial marketing of the product. Slovakia has been one of a few EU member states to allow and to conduct field trials of various bioengineered events.

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.

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 the interim period including 2014. Biotech crops planted in the country in 2014 is 38 hectares comprising biotech cotton (36.3 hectares) and soybean (1.7 hectares). Costa Rica plants commercial biotech crops exclusively for the seed export trade.

Costa Rica is a Spanish speaking country with a population of approximately 4.7 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 2014, approximately 36.3 hectares of biotech cotton were planted commercially, as well as about 1.7 hectares of biotech soybean for a total of 240 hectares. Cotton and soybean are planted in October and harvested in April/May of the following year.

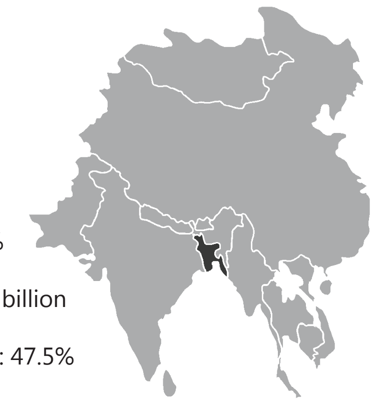
Apart from the commercial production of biotech crops for seed export, Costa Rica is also continuing to field test biotech pineapples, featuring a nutritional quality trait and a disease resistant banana. These field tests were approved under the biosafety regulations of Costa Rica which conform to international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

BANGLADESH

On 30 October 2013, in a landmark historic decision, the Government of Bangladesh demonstrated the political will, courage and commitment in approving the official release of four biotech insect resistant Bt brinjal (eggplant) varieties for limited commercial cultivation. Bangladesh became the first pioneering country in the world to approve the cultivation and consumption of Bt brinjal – a fruit and shoot borer (FSB) resistant biotech brinjal. The Honorable Minister of Agriculture Matia Chowdhury distributed the seedlings of four Bt brinjal varieties to 20 small brinjal farmers on 22 January 2014 – in a record time of less than 100 days after approval. It is very important to note that without the political will

and support from Government, particularly Minister Matia Chowdhury, this feat would not have materialized. Thus the 20 small farmers became the first Bangladeshi farmers to plant Bt brinjal in the spring season of 2014 in four representative regions of Gazipur, Jamalpur, Pabna and Rangpur, where these varieties were well-adapted and carefully monitored. Bt brinjal fruits were successfully harvested from the first plantings in June and July 2014 and sold in local markets and labeled "BARI Bt Begun #, No Pesticide Used" for human consumption. Subsequently, in the winter season of 2014, additional seedlings of Bt brinjal were distributed to 100 more farmers for planting. Winter is the major brinjal growing season contributing 60% of the total 50,000 hectares planted by 150,000 small brinjal farmers in Bangladesh. In summary, 120 small farmers in Bangladesh planted Bt brinjal on 12 hectares in 2014, which is a major step towards increasing the adoption and acceptability of Bt brinjal vegetable in the country.

BANGLADESH



Population: 150.5 million

GDP: US$112 billion

GDP per Capita: US$740

Agriculture as % GDP: 18%

Agricultural GDP: US$20.1 billion

% employed in agriculture: 47.5%

Arable Land (AL): 8.7 million hectares

Ratio of AL/Population*: 0.3

Major crops:

- Rice
- Pulses
- Vegetables
- Wheat
- Potato
- Jute
- Brinjal

Commercialized Biotech Crop: Bt brinjal/eggplant (Begun)

Total area under biotech crops in 2014: 12 Hectares

No. of Bt brinjal farmers: 120

*Ratio: % global arable land / % global population

The Bangladesh Agricultural Research Institute (BARI) in collaboration with the Bangladesh Agricultural Development Corporation (BADC) has undertaken seed multiplication of four additional Bt brinjal varieties to be distributed to farmers in both summer and winter seasons in 2015. Also in 2015, the Bt gene will be introduced into five other popular brinjal varieties viz Dohazari, Shingnath, Chaga, Islampuri and Khatkatia to meet the growing demand for Bt brinjal seeds which will be planted in different brinjal growing areas. Importantly, in the next five years, Bangladesh plans to support the planting of nine brinjal varieties on 20,000 hectares of Bt brinjal, equivalent to approximately 40% of the total 50,000 hectares grown in 20 districts in Bangladesh. The commercial cultivation of Bt brinjal by 120 farmers in 2014 is designed to demonstrate the true value of Bt brinjal technology in farmers' field. To-date, field trials have resulted in a substantial reduction in insecticide sprays and thus lowered the cost of producing a more bountiful harvest of blemish-free brinjal fruits eagerly bought by customers in the marketplace. In essence, Bt brinjal helped farmers to save Bangladeshi Taka 10,000 per hectare on pesticide spraying for controlling FSB

in 2014. Experiments to-date showed that Bt brinjal increases yield by at least 30% and reduces the number of insecticide applications by a massive 70-90%, resulting in a net economic benefit of US$1,868 per hectare over non-Bt brinjal. Thus, it is estimated that at the national level, Bt brinjal has the capacity to generate a net additional economic benefit of US$200 million per year for around 150,000 brinjal growers in Bangladesh.

Why Bt Brinjal in Bangladesh?

Brinjal (*Solanum melongena*), popularly known as Begun, is a very important vegetable in Bangladesh where it is grown by about 150,000 very small resource poor farmers on about 50,000 hectares, in both the winter and summer seasons. Bangladeshis prefer brinjal as one of the key vegetables along with potato and onion. *"Begun bhaja"* is the most popular traditional dish in Bangladesh, which is consumed along with rice and fish curry. Farmers and consumers prefer different types of brinjal, varying in color, shape and size. The Bangladesh Agricultural Research Institute (BARI) – the apex public sector R&D institute has released a dozen brinjal varieties and hybrids in the last three decades for commercial cultivation in different seasons to meet the local requirements (Chowdhury and Hassan, 2013). These conventionally- bred brinjal varieties are very popular among farmers and widely planted in the intensive brinjal growing regions of Rajshahi, Gazipur, Jessore, Dhaka, Pabna, Chittagong, Ishardhi, Barisal, Rangpur, Jamalpur and Rangamati, among others.

Despite commendable achievements in breeding disease resistant and high yielding brinjal varieties, the Bangladesh Agricultural Research Institute (BARI) could not achieve success in breeding brinjal varieties that can impart field level resistance against the major insect-pest of brinjal. The fruit and shoot borer (*Leucinodes orbonalis*) is one of the major insect-pests of brinjal, which causes losses of up to 70% in commercial plantings. It not only damages shoots but also infests fruits, rendering them unfit for sale in the market. It is estimated that the fruit and shoot borer alone reduces marketable produce by about two-thirds (ABSP-II, 2007; Rahman, et al. 2002 and 2009). As a result, farmers are left with little choice except controlling it with insecticides, which invariably prove ineffective. Notably, farmers are often forced to apply insecticides every other day, amounting in some cases up to 80 sprays per season, at an unacceptable environmental cost and an unaffordable price of up to around US$180 per hectare (Kabir et al. 1996; Meherunnahar and Paul, 2009). A socio-economic study on the impact of fruit and shoot borer conducted by the AVRDC (the World Vegetable Centre) in Jessore district of Bangladesh indicated that 98% of farmers relied exclusively on the use of pesticides and more than 60% sprayed their crop 140 times or more in the 6-7 months cropping season (Alam et al. 2003). AVRDC estimated that the pesticides alone contribute to one third of the total cost of production of brinjal, thus, constituting a major cost component of brinjal cultivation in Bangladesh. Significantly, farmers indiscriminately spray insecticides disregarding the recommendation, based on the economic threshold level (ETL), of spraying at an interval of 7-14 days or whenever necessary (Rashid and Singh, 2000). It is reported that the decision of farmers to spray is influenced more by subjective assessment of visual presence of FSB rather than by the more objective science-based methodology of economic threshold levels. This leads to gross over-application of insecticides, higher pesticide residues and needless increase in the farmers' exposure to chemical based insecticides (Choudhary and Gaur, 2009). This is wholly untenable for resource-poor small farmers, their families, environment and unwary consumers who unknowingly purchase and consume brinjal that have often been immersed in insecticides prior to sale in local markets. Readers are referred to ISAAA Brief 47 "The Status of Commercialized Bt Brinjal in Bangladesh" that carries a detailed overview about the agriculture in Bangladesh in general, and the importance of brinjal as a vegetable crop particularly from the point of view of the application of biotechnology in developing FSB resistant Bt brinjal varieties that are effective in reducing cost of cultivation and improving productivity and production of brinjal in the country (Choudhary, Nasiruddin and Gaur, 2014).

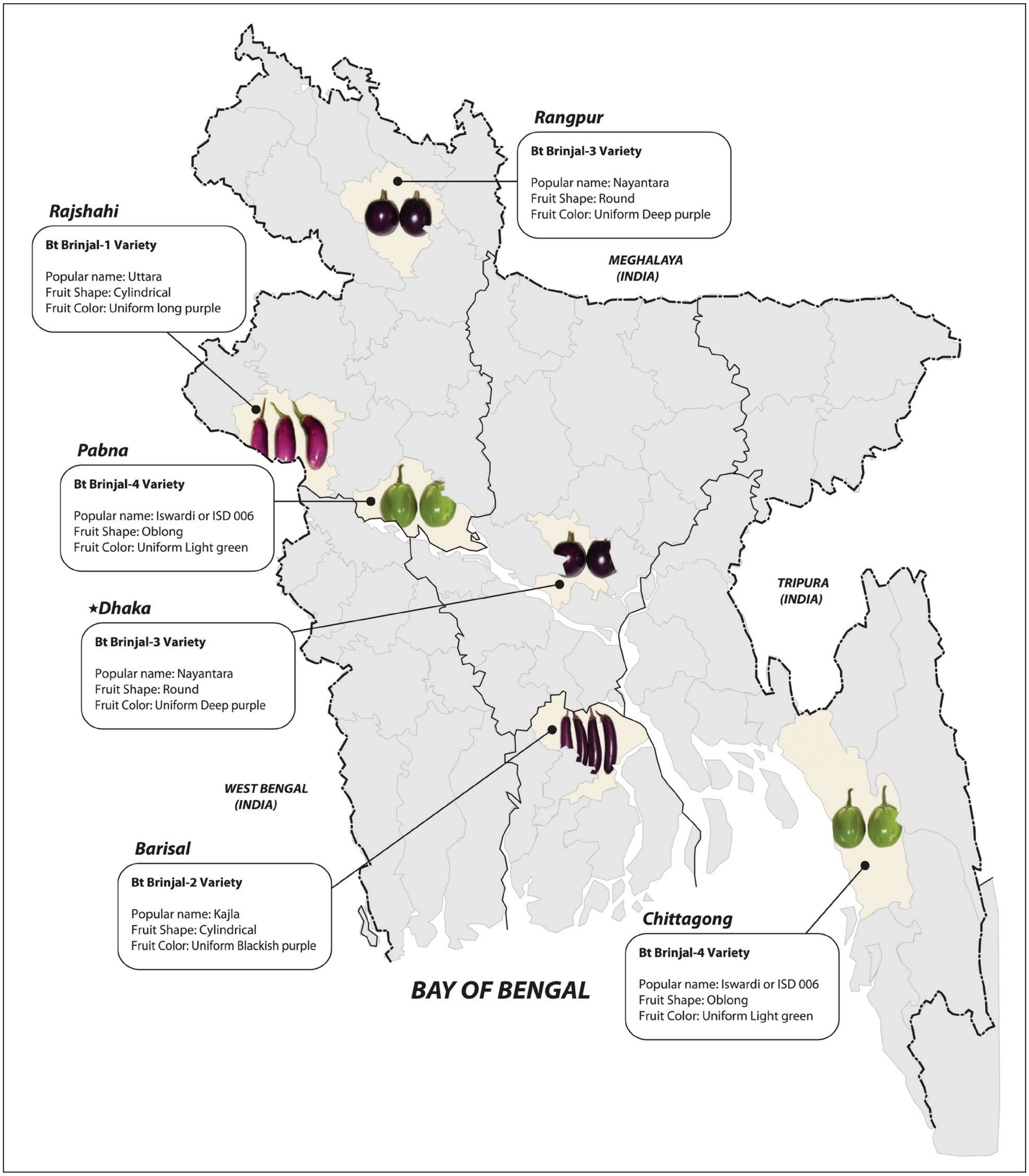
Official Release of Bt Brinjal in Bangladesh

In a landmark historic decision, the Government of Bangladesh approved the official release of four varieties of insect resistant Bt brinjal for commercial cultivation in the country on 30 October 2013 (MOEF, 2013). The Ministry of Environment and Forests (MOEF) issued an official notification, following the approval, for limited cultivation in the fields of four Bt brinjal varieties developed by the Bangladesh Agricultural Research Institute (BARI) of the Ministry of Agriculture, Bangladesh. These four Bt brinjal varieties, named BARI Bt Brinjal-1, BARI Bt Brinjal-2, BARI Bt Brinjal-3 and BARI Bt Brinjal-4, were approved based on the proposal and recommendation of the Bangladesh Agricultural Research Council (BARC), the Ministry of Agriculture (MOA) and the National Committee on Biosafety (NCB) of the Ministry of Environment and Forests. The commercial release notification issued by MOEF directed BARI to comply with the conditions stipulated in the order before release of Bt brinjal varieties in the field (MOEF, 2013). BARI Bt brinjal-1 variety popularly known as Uttara was approved for planting in Rajshahi region whereas BARI Bt brinjal-2 known as Kajla in Barisal region, BARI Bt brinjal-3 known as Nayantara in Rangpur and Dhaka regions and BARI Bt brinjal-4 variety Iswardi/ISD006 in Pabna and Chittagong regions. Figure 29 illustrates the map of Bangladesh indicating the regions where the approved four Bt brinjal varieties were planted.

Table 38 shows the characteristics of different Bt brinjal varieties approved for commercial planting in four major brinjal growing regions of the country. It was the Cornell University-led Agricultural Biotechnology Support Project II (ABSP-II), which facilitated the transfer of Bt brinjal event EE-1 from Indian private seed company Mahyco to the BARI (ABSP-II, 2007; ABSP-II, 2014). BARI later introgressed Bt brinjal event EE-1 into locally adapted and commercially popular open-pollinated brinjal varieties (OPVs) of Bangladesh. Interestingly, the country's Bt brinjal project is primarily a public sector initiative led by BARI, Ministry of Agriculture to develop pro-poor brinjal varieties resistant to FSB (*Leucinodes orbonalis*). Out of the nine popular varieties which were introgressed with Bt event EE-1, four popular ones were approved for commercial cultivation in October 2013 (Table 38). Notably, BARI and BADC – two public sector institutions, have been entrusted with the responsibilities to multiply and distribute the open-pollinated Bt brinjal varietal seeds at a low cost through the public distribution system. Farmers would be able to retain, re-sow and reuse the seeds of these open-pollinated Bt varieties season after season (BARI, 2013). Table 38 shows the eggplant characteristics and the specific area of release.

In addition to commercial approval of 4 Bt brinjal varieties, BARI is also conducting advanced field trials of five additional popular Bt brinjal varieties namely Dohazari, Shingnath, Chaga, Islampuri and Khatkatia that contain Cry1Ac/EE-1 gene (Table 39). These varieties are field tested for their agronomic performance, socio economic and environmental impact assessment and their suitability to other brinjal growing areas where non-Bt counterparts are popular. It is expected that the Government of Bangladesh will consider approval of 5 additional Bt brinjal varieties for commercial release in the near

Figure 29. Map of Bangladesh Illustrating Approval of Insect Resistant Bt Brinjal Varieties Corresponding to Planting Regions



Source: Compiled by ISAAA, 2014

Table 38. Commercial Release of Four Bt Brinjal Varieties in Bangladesh, 2013-14

Variety/Popular name	Fruit shape	Fruit color	Region of Bt brinjal release
Bt Brinjal-1/Uttara	Cylindrical	Uniform Light purple	Rajshahi
Bt Brinjal-2/Kajla	Cylindrical	Uniform Blackish purple	Barisal
Bt Brinjal-3/Nayantara	Round	Uniform Deep purple	Rangpur and Dhaka
Bt Brinjal-4/Iswardi or ISD 006	Oblong	Uniform Light green	Pabna and Chittagong

Source: Rashid and Singh, 2000; Chowdhury and Hassan, 2013; MOEF, 2013; Compiled by ISAAA, 2014.

Table 39. Five Bt Brinjal Varieties Field Tested and Pending Approval for Commercialization, 2014-15

Variety/Popular name	Fruit shape	Fruit color
Bt Brinjal-7/ (Singhnath)	Long Cylindrical	Deep purple
BL117/Khatkhatia	Cylindrical	Greenish purple
BL072/Dohazari	Oblong	Green with white stripe
Islampuri	Round	Uniform Deep Purple
Chaga	Oblong	Uniform Light Green

Source: BARI, 2014; Compiled by ISAAA, 2014.

future covering remaining brinjal growing areas of Bangladesh. Table 39 shows the characteristics of five Bt brinjal varieties in the final stage of field testing for possible approval in 2015.

Adoption of Bt Brinjal in Bangladesh

Bangladesh officially approved the release of four biotech insect resistant Bt brinjal varieties for seed production and initial commercialization on 30 October 2013. The planting of Bt brinjal started in early 2014 in the spring (Basanta) season and continued in winter (Sharat) season. After the commercial release of Bt brinjal by MOEF, BARI raised 30-35 day old Bt brinjal seedlings of four Bt brinjal varieties to ascertain the purity and quality of Bt brinjal seedlings to be distributed to farmers. On 22 January 2014, Honorable Minister of Agriculture, Ms. Matia Chowdhury distributed the seedlings of four Bt brinjal varieties to 20 small brinjal farmers in a forum, jointly organized by BARI, the Bangladesh Agricultural Research Council (BARC) and USAID in Dhaka, Bangladesh. Of 20 farmers, five farmers each belonged to the four important brinjal growing regions including Gazipur, Pabna/Ishurdi, Jamalpur and Rangpur. Each farmer was given Bt brinjal seedlings for planting one bigha (about 0.13 hectare) representing 5 bigha for each region. These seedlings were sufficient to plant a total of 2 hectares of Bt brinjal in the spring season of 2014 (Financial Express, 2014; Daily Star, 2014; Dhaka Tribune 2014; New Age, 2014; BD News 24, 2014).

BARI supervised the plantings of Bt brinjal seedlings and monitored each farm throughout the crop life cycle to ensure strict compliance with Bt brinjal release notification issued by MOEF on 30 October

Table 40. Adoption of Bt Brinjal in Bangladesh in 2014

Year	Adoption of Bt Brinjal (ha)	Total Brinjal Area (ha)	Number of Bt Brinjal Farmers	% Adoption
2014	12	50,000	120	<1

Source: Compiled by ISAAA, 2014.

2013. BARI also organized farmer's field days in each region to demonstrate field performance of Bt brinjal to neighboring farmers and dispel misconception and worries of consuming Bt brinjal. Each field day attracted hundreds of farmers and consumers and was attended by policy makers from various departments of the Government of Bangladesh. Bt brinjal technology exhibited effective protection for the fruit and shoot borer (FSB) in each of the 20 fields. Bt brinjal allowed farmers to raise healthy and vigorous brinjal crop substantially cut down pesticide spraying to control FSB and significantly reduced cost of cultivation. A few Bt brinjal farmers reported wilting of plants that was primarily caused by the prevalence of pathogen due to off-season planting of Bt brinjal in the spring season (The Guardian, 2014). On average, farmers harvested bountiful, fresh and non-infested brinjal fruits, which were sold in the local market labelled as "BARI Bt Begun #, No Pesticide Used". Subsequently, in the winter season of 2014, BARI along with BADC distributed the seedlings of four Bt brinjal varieties to additional 100 farmers which were planted by each farmer on 1 bigha totaling10 hectares. Bt brinjal plants were at vegetative growth at the time of finalizing this brief therefore the details of the performance and socio-economic impact of the large scale cultivation of Bt brinjal in Bangladesh will be included in the next ISAAA brief.

In the first year of the limited commercial planting in 2014, Bangladesh planted a limited area of approximately 12 hectares of Bt brinjal by 120 farmers in two seasons – 2 hectares by 20 farmers in spring season and 10 hectares by 100 farmers in the winter season of 2014 (Table 40). Similarly, the large scale seeds production of four Bt brinjal varieties, including Bt Brinjal-1 (Uttara), Bt Brinjal-2 (Kajla), Bt Brinjal-3 (Nayantara) and Bt Brinjal-4 (Iswardi/ISD 006) were undertaken by BARI in collaboration with BADC in 2014. In summary, 120 farmers planted 12 hectares of Bt brinjal in 2014 which is a precursor to the wide scale adoption of Bt brinjal in Bangladesh where brinjal occupies the total estimated brinjal area of 50,000 hectares planted by about 150,000 farmers.

The experience of initial limited planting of Bt brinjal in both spring and winter seasons of 2014 shows that Bt technology is set to mitigate economic losses to the farmers and substantially increase the marketable yield. Notably, the limited commercial cultivation of Bt brinjal by 120 farmers demonstrated the true value of Bt brinjal technology in farmers' field. Bt brinjal farmers substantially reduced insecticide sprays and thus the cost of production, and obtained bountiful blemish free brinjal fruits with good marketability.

Previous experiments showed that Bt brinjal increases yield by at least 30% and reduce the number of insecticide applications by a massive 70-90% resulting in a net economic benefit of US$1,868 per hectare over non-Bt brinjal (Islam and Norton, 2007). It is estimated that at the national level, Bt brinjal has the capacity to generate a net additional economic benefit of US$200 million per year for around 150,000 brinjal growers in Bangladesh.

Co-development and De-regulation of Bt Brinjal

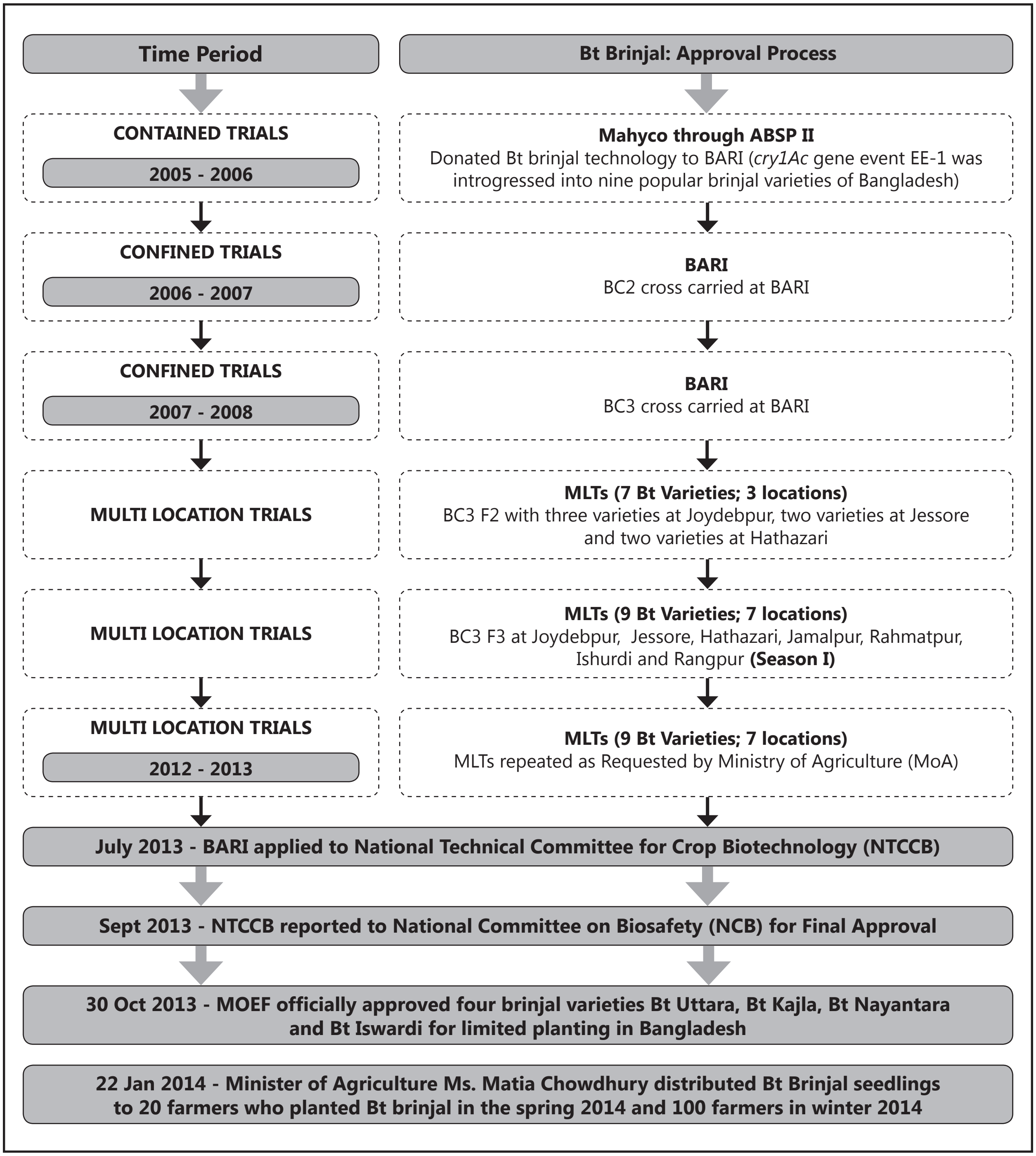
Bt brinjal is one of the world's first successful biotech crop projects involving a tripartite arrangement between public R&D institute (BARI), private seed company (Mahyco) and regulatory agency in Bangladesh under a USAID led program – the Agricultural Biotechnology Support Project II (ABSP-II). Bt brinjal project is a good example of a successful public-private partnership to develop pro-poor Bt brinjal varieties in Bangladesh using state of the art biotech trait. The project involved transfer of technology from India to Bangladesh, development of locally adaptable brinjal varieties with biotech trait and deregulation under sovereign regulatory system and delivery of biotech seeds to farming community. The technology was generously donated by an Indian company Mahyco and brokered under the aegis of the Agricultural Biotechnology Support Project II (ABSP-II) managed by the Cornell University (ABSP-II, 2014). As a part of the tripartite project, Mahyco donated the Elite Event (EE-1) to BARI in 2005. BARI introgressed the Elite Event-1 into 9 popular brinjal varieties to express an insecticidal protein cry1Ac and effectively control the infestation of target insect-pest, the fruit and shoot borer (FSB). BARI chose to develop the open pollinated varieties of Bt brinjal in order to provide affordable seeds to farmers in Bangladesh. Contrary to hybrid Bt brinjal, farmers in Bangladesh can reuse seeds of Bt brinjal varieties for planting season after season. These 9 open pollinated brinjal varieties were subjected to rigorous testing under the biosafety and regulatory system of Bangladesh.

Figure 30 describes the chronological development of Bt brinjal in Bangladesh. Bt brinjal was field tested under contained, confined and open field condition for 7 consecutive seasons from 2005-06 to 2013-14. The contained and confined field trials were undertaken for 9 Bt brinjal varieties from 2005-06 to 2007-08. The first set of multi-location field trials were carried out in 2008-09 for 6 Bt brinjal varieties, Uttara, Dohazari, Nayantara, Shingnath, ISD006 and Chaga at three distinct brinjal growing areas of Joydebpur, Jessore and Hathazari. Subsequently in 2010-11 and 2011-12, two-season multi-location field trials were carried out involving all 9 Bt brinjal varieties including additional three Bt brinjal varieties – Kajla, Islampuri and Khatkatia, These trials were held in seven locations of Joydebpur, Jessore, Hathazari, Jamalpur, Rahamatpur, Ishurdi and Rangpur that represented major brinjal growing areas of the country. Apart from this, multi-location field trials of 9 Bt brinjal varieties were conducted again in 2012-13 in response to the instructions from the Ministry of Agriculture to revalidate the agronomic performance and environmental effects of Bt brinjal. These seven years of rigorous field testing of Bt brinjal were conducted under the direct supervision of the public sector scientists of BARI under the aegis of Ministry of Agriculture in compliance with the biosafety and regulatory guidelines of the Ministry of Environment and Forests.

To comply with the Bangladeshi regulatory process, a set of biosafety studies were conducted to confirm that Bt brinjal causes no adverse effects on humans, wild and domesticated animals, birds, fishes and non-target insects, including beneficial insects. The nutritional studies carried out by the Dhaka University confirmed that Bt brinjal is substantially equivalent to its non-Bt counterpart. In addition, the feeding studies on chicken, cow and fish showed no sign of toxicity and allergenicity and found it to be safe for consumption. The studies also confirmed that Bt protein was undetectable in cooked brinjal fruits. On the whole, the biosafety studies have shown no significant differences between Bt brinjal and its non-Bt counterparts.

On completion of all the biosafety studies on Bt brinjal in Bangladesh, BARI submitted the biosafety

Figure 30. Chronology of the Regulatory Approval of Bt Brinjal in Bangladesh, 2005 to 2014



Source: Adapted from Choudhary, Nasiruddin & Gaur, 2014; Compiled by ISAAA, 2014 dossier of Bt brinjal to the National Technical Committee for Crop Biotechnology (NTCCB) of the Ministry of Agriculture seeking approval of Bt Brinjal in 2013. The NTCCB constituted an experts committee to evaluate and review the biosafety data submitted by BARI. In Sept 2013, the expert committee reviewed and validated scientific testing and findings as rigorous and technically sound and submitted its report to the Ministry of Agriculture. The NTCCB reexamined the expert committee report and sent its recommendation for approval of Bt brinjal to the National Committee on Biosafety (NCB) of the Ministry of Environment and Forests which is the apex regulatory body empowered to accord the commercial approval of GM crops in Bangladesh. In a landmark decision, the NBC approved limited cultivation of four Bt brinjal varieties. Consequently, the Ministry of Environment and Forests issued a notification for the official release of four varieties of Bt brinjal for limited cultivation in the country on 30 October 2013 (MOEF, 2013). In addition, BARI has been field testing five other Bt brinjal varieties that are at an advanced stage of regulatory approval in Bangladesh. It is expected that the Government of Bangladesh will consider the approval of 5 additional Bt brinjal varieties for commercial release in near future covering remaining brinjal growing areas of Bangladesh.

Importance of GM Crops in Bangladesh

Biotech crops offer an immense opportunity to transform agriculture in Bangladesh where majority of the people depends largely on agriculture. Agriculture contributes 20% of the gross domestic product (GDP) of US$115 billion with an annual per capita income as low as US$700 (FAO, 2013). The majority of crops are constraint with severe biotic and abiotic stresses further compounded by depleting soil fertility, unfavorable environment and effects of climate change. Several important crops including rice, maize, potato and cotton are being developed using biotech traits to overcome biotic and abiotic stresses. These crops are developed under the R&D collaboration between public-public and public-private partnerships and/or under bilateral arrangements. Bt brinjal is the first and the foremost example of the successful partnership in Bangladesh which is now being commercially planted in farmers' field. The successful release of Bt brinjal paves the way for other principal biotech crops to be evaluated and commercialized in Bangladesh. The late blight resistant (LBR) potato and Bt cotton are two other important biotech crops that are field tested in Bangladesh. Golden Rice is an important biotech crop that is developed and tested extensively in Bangladesh in collaboration with the International Rice Research Institute.

In addition to Bt brinjal, ABSP-II facilitated the transfer of the Rb gene technology from the University of Wisconsin to BARI to develop late-blight resistant potato varieties, suitable for the major potato growing areas in Bangladesh. Rb gene is sourced from *Solanum bulbocastanum*, a wild relative of potato and introgressed into two popular potato varieties using gene transfer technology (GAIN, 2014). The biotech potato varieties confer resistance to the lethal fungal disease caused by *Phytophthora infestans* that causes devastating losses world-wide estimated at US$7.5 billion annually in potato. It is estimated that late blight disease can cause yield losses ranging from 19% to as much as 75% in Bangladesh. Farmers apply numerous sprays to save their potato crop planted annually on over a quarter of a million hectares in Bangladesh. Potato alone consumes approximately 80-85% of total fungicides applied in agriculture in Bangladesh (USAID, 2013; ABSP-II, 2014; Islam and Norton, 2007). The field trials of late blight resistant potato varieties conducted by BARI in Bangladesh indicate a substantial reduction in fungicide cost of US$77 per hectare, minimum yield increase of 15% resulting in a net benefit of US$821 per hectare. Islam and Norton estimated that LBR potato can contribute sizable social benefits to potato growers and can generate farm benefits estimated at US$261 million, over a ten year period.

Bangladesh is one of the largest consumers of raw cotton and uses approximately 4 to 4.5 million bales of cotton to spin a product for the textile sector. The textile and garment sector contributes around 13% of the Gross National Income and are a major source of foreign earnings accounting for about 78% of the total export income. Domestic raw cotton production is abysmally low, with an annual production of 140,000 bales from a total cotton area of 40,000 hectares planted by 70,000 farmers. Bangladesh can only meet 2-3% of the total raw cotton demand of the textile sector and hence relies heavily on imported raw cotton and fibers from India, USA and Uzbekistan. Bangladesh is the second largest importer of cotton fiber in the world. The Cotton Development Board (CDB) of the Ministry of Agriculture estimates that the demand for cotton fiber will increase by three-fold from 800,000 tons in 2014 to 2,500,000 tons by 2020 driven by the global demand for clothing and textiles manufactured in Bangladesh (Uddin, 2014).

In order to increase the domestic supply of raw cotton, the Government of Bangladesh has shown commitment to increase cotton production by introducing new and improved varieties of cotton hybrids and genetically modified Bt cotton. The neighboring countries including India, China, Myanmar and Pakistan have already introduced Bt cotton and significantly increased cotton production in the last couple of years. In recent years, the Cotton Development Board has field tested the first genetically modified Bt cotton hybrid sourced from Chinese Hubei Seeds under a bilateral agreement (Uddin, 2014). **GAIN (2014) reported that the Cotton Development Board will seek approval of Bt cotton from the National Committee on Biosafety (NCB) for domestic cultivation in the near future (GAIN, 2014; Bhuyan, 2014).**

In June 2014, Bangladesh Minister of Agriculture Ms. Matia Chowdhury while inaugurating the 6th Meeting of the Asian Cotton Research & Development Network of ICAC in Dhaka, called on neighboring countries including India and China to assist Bangladesh in accessing and introducing Bt cotton. She reiterated the Government's commitment to genetically modified crops and stated that ***"Genetically Modified (GM) for cotton is another important issue for Bangladesh. Bangladesh Government has approved biosafety rule for the introduction of GMO crop. Within this time, Government of Bangladesh has approved the Bt Brinjal for growing at the farmer's level. Very urgently we are trying to introduce Bt cotton in the country. China, India and other many cotton growing countries are more advanced in Bt cotton cultivation and they have increased their national cotton production through the introduction of Bt cotton. They can provide assistance for introduction of Bt cotton in Bangladesh. ICAC can also extend their cooperation for introducing Bt cotton in Bangladesh"*** (ICAC, 2014).

Farmers' Commitment and Consumers Understanding are Critical for Large Scale Adoption of Bt Brinjal in Bangladesh

Bt brinjal is an exemplary model of a public-private partnership for the successful delivery of benefits from the-state-of-the art biotechnology to resource poor farmers in Bangladesh. Many countries in Asia and Africa have been attempting to introduce genetically modified crops can learn and emulate the success of Bangladesh's Bt brinjal model in translating the technology partnership into a reality at the farmer level. In 2014, the first year of commercialization, Bt brinjal significantly increased the marketable yield of brinjal fruits thereby mitigating losses caused by wastage of infested and damaged fruits. Previous experiments showed that Bt brinjal increases yield by at least 30% and reduce the number of insecticide applications by a massive 70-90% resulting in a net economic benefit of US$1,868 per hectare over non-Bt brinjal (Islam and Norton, 2007). It is estimated that at the national level, Bt brinjal has the capacity to generate a net additional economic benefit of US$200 million per year for around 150,000 brinjal growers in Bangladesh.

Indirectly, farmers and their families enjoyed invaluable benefits in terms of escaping health problems due to a substantial reduction in direct exposure to insecticides. Higher net benefit, estimated at around US$1,868 per hectare is a princely sum for smallholder farmers which should trigger a large scale adoption of Bt brinjal among growers across the country in subsequent seasons. BARI estimated that Bt brinjal will occupy approximately 20,000 hectares or 40% of total 50,000 hectares across 20 districts under nine Bt brinjal varieties in next five years in Bangladesh.

However, the large scale adoption of Bt brinjal will also come with an enormous responsibility to educate and increase awareness of Bt brinjal farmers and consumers. Farmers have to be educated about the importance of implementing insect resistant management schemes and stewardship programs that will play a significant role in the large scale durable adoption and acceptance of Bt brinjal. Farmers need to acquire new skills, techniques and farm practices to comply with the conditions that are necessary in order to sustainably reap bountiful harvests of Bt brinjal. At the same time, public understanding of Bt brinjal will become paramount in the acceptance of technology at the consumer level. These are the two important responsibilities for farmers and consumers that are essential for the long term success of Bt brinjal in Bangladesh. The following measures are required to sustain improved productivity of Bt brinjal at the farmer and consumer level in Bangladesh;

- Farmers must exercise diligence in planting a refuge every time they grow Bt brinjal.
- Insect resistance management and stewardship schemes are two key elements of biotech crops that must be put in place for successful and sustainable production of Bt brinjal.
- BARI must ensure the purity and adequate expression of the Bt trait while producing and distributing Bt brinjal seeds or seedlings to farmers.
- BARI may also involve the private sector seed companies to produce and maintain the purity and high quality of Bt brinjal varietal seeds.
- The Government of Bangladesh can also harness the skills and competence of the private seed industry which is actively promoting R&D, production and distribution of high yielding seeds and planting material.
- The Government of Bangladesh could provide an incentive for private seed companies to develop brinjal hybrids with Bt technology to maximize the yield potential of the brinjal crop.
- Private companies should also be proactive in increasing investments in R&D of new genes, pyramiding of genes and stacking of traits to enhance the value and durability of Bt brinjal technology
- NGOs and others involved in welfare activities should adopt a coherent approach and work in tandem with public sector institutions to educate and help farmers overcome knowledge deficits associated with new technology.
- Government of Bangladesh may launch a country wide communication and outreach program

to educate and inform the public about the need for new technologies such as Bt brinjal to overcome the issues related to frequent shortage and high price of vegetables, food production and food security.

THE EUROPEAN UNION (EU 27)

Five EU countries continued to plant 143,016 hectares of biotech Bt maize in 2014, equivalent to a ~3% decrease over 2013 at 148,013 hectares. The five countries, the same as last year, in decreasing order of hectarage were, Spain, Portugal, Czechia, Romania and Slovakia. Spain was by far the largest Bt maize grower with 92% or 131,538 hectares of the total 143,016 hectares maize in the EU. Bt maize adoption in Spain was up marginally at 31.6% compared with 31% in 2013, despite a 4% decrease in total hectares. Bt maize hectarage was up in three countries Portugal, Romania and Slovakia and down in two countries Spain and Czechia. The decreases in Bt maize were marginal and associated with several factors, including less total hectares of maize planted in 2014, disincentives for some farmers due to bureaucratic and general onerous reporting of intended plantings of Bt maize, and in some cases a limited seed supply. Provisionally, the EU (excluding Spain) is estimated to have enhanced farm income from biotech maize by US$20.8 million in the period 2006 to 2013 and the benefits for 2013 alone is US$1.7 million.

The European Union comprises 28 states (as of July 2013, with the ascension of Croatia), a population of almost 500 million (7% of global) with a GDP in 2014 of US$13 trillion, equivalent to over 18% of global GDP. Around 2% 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 41 summarizes the planting of Bt maize in the countries of the European Union from 2006 to 2014.

Five EU countries continued to plant 143,013 hectares of biotech Bt maize in 2014, equivalent to a ~3% decrease over 2013 at 148,013 hectares. The five countries, the same as last year, in decreasing order of hectarage were Spain, Portugal, Czechia, Romania and Slovakia. Spain was by far the largest Bt maize grower with 92% or 131,538 hectares of the total 143,474 hectares maize in the EU. Bt maize hectarage was up 829 hectares in Portugal, 551 hectares in Romania, and 311 hectares in Slovakia; hectarage decreased by 5,424 hectares in the largest Bt maize country Spain (due to less total plantings) and 806 hectares in Czechia due to disincentives for some farmers that arise from bureaucratic and onerous reporting of intended plantings of Bt maize, and a limited seed supply. In summary in 2014, hectarage of 143,016 hectares were planted in the EU with a marginal decrease of 3% compared to 2013.

All five EU countries which grew Bt maize commercially in 2014 provided benefits to farmers, to the

Table 41. Hectares of Bt Maize Planted in EU Countries in 2006 to 2014*

	Country	2006	2007	2008	2009	2010	2011	2012	2013	2014
1	Spain	53,667	75,148	79,269	76,057	76,575	97,326	116,307	136,962	131,538
2	Portugal	1,250	4,263	4,851	5,094	4,868	7,724	9,278	8,171	8,542
3	Czechia	1,290	5,000	8,380	6,480	4,680	5,091	3,080	2,560	1,754
4	Romania*	– –	350	7,146	3,244	822	588	217	220	771
5	Slovakia	30	900	1,900	875	1,248	761	189	100	411
6	Germany*	950	2,685	3,173	– –	– –	– –	– –	– –	– –
7	Poland	100	327	3,000	3,000	3,000	3,000	N/A	– –	– –
	Total	**57,287**	**88,673**	**107,719**	**94,750**	**91,193**	**114,490**	**129,071**	**148,013**	**143,016**

* 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, 2014.

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, the European biotech industry warned the EU Commission that slow approval of biotech crop imports, critical as feed-stocks, poses 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 of global feed exporting countries like Brazil expediting approval of biotech crops (8 products approved in 2010 alone, 6 in 2011, and 3 in 2012, and 1 in 2013), whilst the EU is slowing down its approval process. On average, the EU's approval process is at least 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 requests 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. 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. Only a total of two biotech crops were approved for cultivation in the EU (Bt maize and Amflora potato) compared with 157 in the US and 37 in Brazil by 2013.

The EU Commission drafted a proposal in 2010 to empower individual 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). The European Commission proposed to let individual member states to ban or allow a GM crop in their territory, while the commission would still give marketing approvals for European countries based on the scientific opinion released by European Food Safety Authority (EFSA). That proposal was revived in February 2014 when states debated over the approval of a GM maize line. Twenty six of the 28 member states agreed on this "cultivation proposal" on June 12, 2014 as a practical compromise. In the coming months, Europe's Council of Ministers must agree on a joint version of the plan with the incoming European Parliament before the final text can be adopted, possibly in 2015 (Crop Biotech Update, 18 June 2014).

The 2014 EU Innovation Scoreboard shows that EU needs revitalized innovation and industry. It was also reported that there is an improvement in closing the innovation divide with the rest of the world. However, Europe is still behind in innovations compared with countries such as Japan, South Korea and the US. The critical state of innovative industries such as the biotechnology industry in Europe today and the need for concrete action, go beyond the improvement of research and development funding which has taken place in Europe. Thus, André Goig, EuropaBio Chairman commented that, ***"Unless Europe can guarantee such improvements, coupled with science-based, predictable and workable regulatory systems for small and large companies, as well as tailored market pull measures for innovative products and faster and more equitable access to products for end users, similar to those available in other parts of the world, we are setting ourselves up to keep losing, not only on the scoreboard but most importantly in terms of jobs, growth and benefits for society"*** (Crop Biotech Update 12 March 2014).

Cost of NOT Employing Biotech Crops

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 sugar beet were to be grown where there is agronomic need or benefit, then farmer margins would increase by between €443 million (US$576 million) and €929 million (US$1.2 billion) 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 sugar beet 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 sugar beet, 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."

The EU (excluding Spain) is estimated to have provisionally enhanced farm income from biotech maize by US$20.8 million in the period 2006 to 2013 and the benefits for 2013 alone is US1.7 million (Brookes and Barfoot, 2015, Forthcoming).

Opinions on GM Crop Policy in EU

A review of EU policies was recently conducted by the European Academies Science Advisory Council (EASAC). The policy report covers the opportunities and challenges of using crop genetic improvement technologies for sustainable agriculture. It highlights a number of inconsistencies in the current policy landscape of the European Union (EU). These include:

- the approval of GM crop importation and disapproval of the same GM crop for cultivation within the EU;
- the commitment to invest in plant science but neglects the use of certain agricultural innovation;
- and the goal to reduce chemical pesticide but over-regulates alternative approaches in crop protection.

The report also said that rapid changes in the distribution in agriculture are happening worldwide but EU has declined from some world markets. Crop genetic improvement technology is one valid tool towards sustainable intensification of agriculture, and implementing policies against such tools is unwise (Crop Biotech Update, 3 July 2013). "Fortuna", a GM potato resistant to late blight, developed by BASF was already at the final stages of the approval process before commercialization when the company announced discontinuation of its regulatory pursuit. Two other amylopectin starch GM potato events Amadea and Modena developed by BASF were also withdrawn from the approval process. In a press release, BASF said that it will ***"discontinue the pursuit of regulatory approvals for these three potatoes in Europe because continued investment cannot be justified due to uncertainty in the regulatory environment and threats of field destructions"*** (Crop Biotech Update, 6 February 2013). Thus, because of the slow EU process of approval, the biotech late blight potato will not be available in the near term – a loss to the farmers, consumers and EU society at large.

Late blight potato is the most promising GM crop in the EU that would significantly reduce the number of pesticide applications used to control the disease and would bring significant environmental benefits. Different EU public institutions in various countries (UK, Netherlands, Ireland and Belgium) have different versions of a late blight resistant potato underway, but they are not as advanced as was the cases with the BASF product "Fortuna".

Despite the general apathy at the political level in the EU for biotech crops there are world class scientific centers of excellence conducting state-of-the-art research at many laboratories in the EU. For example the VIB lab, in Ghent, Belgium founded by the 2013 World Food Prize laureate Marc Van Montagu is involved in a broad range of cutting-edge biotech activities. The VIB department of Plant Systems Biology is located in Ghent (Belgium) and is headed by Dirk Inzé. The department evolved from the lab of Marc Van Montagu who together with Jeff Schell unraveled the gene transfer mechanism of *Agrobacterium*. Van Montagu's and Schell's knowledge was instrumental in developing the first genetically modified plants. The PSB department still operates at the forefront of plant sciences and integrates genetics, genomics and biocomputing to explore the potential of plants to contribute to a more sustainable agriculture and secure world.

In The Sainsbury Laboratory (TSL) in the UK, a three year late blight resistant potato project was recently concluded. The potatoes experienced ideal conditions for late blight and scientists did not inoculate any plants, but waited for races circulating in the UK to blow in. By early August, non-transgenic plants were 100% infected while all GM plants remained fully resistant until end of the experiment. The GM tubers also yielded more than the non-GM tubers. The introduced gene came from a South American wild relative of potato, and it triggers the plant's natural defense mechanisms by enabling it to recognize the pathogen. TSL Professor Jonathan Jones and study proponent opined that GM technology, together with the insights into both the pathogen and its host, will help them tip the evolutionary balance in favor of potatoes and against late blight (Crop Biotech Update, 19 February 2014).

Biotech Endorsement by EU's Scientific Bodies

UK Council for Science and Technology (CST) released a letter to the Prime Minster about the risks and benefits of biotechnology and what the government can do to enhance the quality of debate, decision-making and regulation in the UK and Europe. It was stressed in the letter that the public should have confidence in the consensus on the scientific evidence that GM products are as safe as their conventional counterparts. Despite this growing evidence, regulations of GM commercialization remain more stringent than that imposed on crops developed through conventional breeding.

The letter cited reports of highly-credible institutions about biotechnology. One report mentioned was the 2009 Royal Society report titled "Reaping the benefits" which provides sound bases of evidence on GM in food production. CST also endorsed the EASAC report which recommended re balancing of the EU regulatory process to focus on products rather than technologies and on risk-benefit instead of the risk per se. Thus, CST asked for a right regulatory framework that will encourage continued research into solutions to current and future problems facing UK agriculture (Crop Biotech Update, 19 March 2014).

A large coalition representing Europe's agricultural and food business sectors is calling for better and smarter policy-making that fosters innovation and creates jobs, ensuring that the EU agri-food chain becomes more productive and resource-efficient. The group of 11 EU-level associations presented a joint statement, "Vision for unlocking the potential of agriculture and food industries in the EU" during the meeting of EU Ministers for Agriculture in Athens on 6 May 2014. The coalition includes suppliers of machinery, seed, fertilizers, crop protection, animal health, feed and biotechnology-based products, EU farmers and the European food and drink sector. The 'Joint Vision', underlines the importance of providing a secure and safe supply of food not only for EU citizens, but also beyond Europe's borders, and to do so in a sustainable and environment-friendly manner. The group is united in its call for a more streamlined EU policy agenda that places the promotion of innovation at its very core in order to sustain a safe, high-quality and affordable food production and consequent choice for consumers (Crop Biotech Update, 2014).

In response to the request of the European Commission, the European Food Safety Authority (EFSA) assessed the documents forwarded by France in support of its request to ban the planting of GM maize MON810 in the EU. According to EFSA, the scientific publications and the arguments forwarded by France do not provide any new information that would change the previous risk assessment conclusions and risk management recommendations released by the EFSA GMO Panel. EFSA considers that the previous

GMO Panel risk assessment conclusions and risk management recommendations on MON 810 are still valid and applicable. Thus, EFSA concluded that there is no specific scientific evidence, in terms of risk to human and animal health or the environment, that would support the adoption of an emergency measure on the cultivation of maize MON 810 (Crop Biotech Update, 6 August, 2014).

Political Support to Biotech Crops in the EU

Alan Lacey, new chairman of the Society of Food Hygiene and Technology (SOFHT) said in a recent interview that genetically modified (GM) foods should not be scary, and that the benefits of GM foods outweighed the arguments against it. ***"It shouldn't be scary, there's got to be an illustration of the benefits of GM to consumers. Consumers want the choice and they want the power to buy what they want to buy."*** He added ***"that GM food offered consumers and food manufacturers many benefits including shelf life, taste, and nutrition"*** (Crop Biotech Update, 30 August 2014).

Food Safety Authority of Ireland (FSAI) Chief Executive, Alan Reilly, said that it is time to put aside irrational and non-science based fears of new technologies in the interest of consumers everywhere. In his article in the FSAI newsletter titled *Genetic Modification - Are the Food Safety Concerns Still Justified?*, he said that GM food remains to be one of the most controversial aspects of European food law. **"If Europe is to remain at the forefront of research and innovation in the agri-food arena, policies need to be developed now to guide the exploitation of this new genetic modification technology"** (Crop Biotech Update, 3 September 2014).

Former European Union commissioner Franz Fischler said that halting imports of GM soybean would be detrimental for Europe's egg producers. He mentioned this warning during the International Egg Commission conference held in Vienna, Austria. Fischler was the EU agriculture commissioner from 1995 to 1999. ***"Europe is very weak in soya production or other protein plants, so most of the protein is imported,"*** he discussed. Nearly two thirds of the protein plants used in Europe were soybean and more than 90 percent of that was imported, he added. ***"It is clear that we in Europe would have to stop production if we couldn't import any more genetically modified soya products. This is absolutely clear. Anything else is an illusion,"*** he said to the delegates of the conference. ***"I know that some, especially unfortunately in my own country (Austria), say we need a total ban on genetically modified products, but the consequence would be that we would import the eggs and the poultry instead of the feeding stuffs. That, for some of you, would be perfect, but for European producers it would be a catastrophe"*** (Crop Biotech Update, 30 April 2014).

Farmer Testimonies and Stakeholder Views

In a 2013 UK survey, more than half (61%) of the 625 respondent British farmers confirmed that they are willing to grow GM crops if it is legal to do so. According to them, the key advantages of the technology are:

- reduction in environmental impact of farming
- becoming at par with other GM crop farmers overseas
- cutback in cost of production.

Some 47 percent of the respondents perceived GM technology as a good innovation which can be used by UK agriculture to maximize productivity and profitability (Crop Biotech Update, 20 June, 2013).

The United Kingdom study ***Feeding the Future: Innovation Requirements for Primary Food Production in the UK to 2030*** reported that the country's primary producers identified the development of modern technologies and genetic modification (GM) as the top two research areas that should be prioritized in the country. The report sets out the UK industry's top research and development focus for the first time (Crop Biotech Update, 20 June 2013).

Irish Farmers Association (IFA) national potato chairman Thomas Carpenter said there is an onus on EU society to examine how biotechnology can be used to reduce substantially the significant crop yield loss that growers are experiencing, while also addressing environmental concerns. Carpenter said ***"Robust independent research coupled with a properly designed education program is needed to help consumers to understand the benefits that biotechnology can deliver"*** (Crop Biotech Update 16 October 2013).

Progress with Biotech Crops in Africa

In 2014, Africa continued to demonstrate a keenness for modernized agriculture through the slogan ***"Ripe for Change: The Promise of Africa's Agricultural Transformation".*** Calls to embrace science, technology and innovation intensified. Biotech tools featured prominently and the growth momentum for GM/biotech crops was maintained. Three countries – South Africa, Burkina Faso and Sudan continued taking the lead in commercialization of biotech cotton, maize and soybean. Additionally, expansion of multi-location trials for important cash and food crops continued with extension of approved confined field trials in all four sub-regions.

The map of Africa (Figure 31) provides a self-explanatory summary of the three countries that continued to grow biotech crops and seven additional countries that sustained conduct of field trials of biotech crops in 2014. These are: Cameroon, Egypt, Ghana, Kenya, Malawi, Nigeria and Uganda. The key crops at various stages of experimentation in both confined and open trials include banana, cassava, cotton, cowpea, maize, rice, sorghum, sweet potato and wheat.

Similar to 2013, the on-going trials focus on traits of high relevance to challenges facing Africa, key among them drought, nitrogen use efficiency, salt tolerance and nutritional enhancement, as well as resistance to tropical pests and diseases. The expanding number of 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 are being conducted under the aegis of existing legislation or stand-alone biosafety structures.

A range of policy pronouncements in support of biotechnology and regulatory capacity development efforts intensified in 2014. In her address during the 3rd Annual African First Ladies discussion on science, technology, engineering and mathematics in September, 2014, the African Union Commission Chairperson, Nkosazana Dlamini Zuma recognized biotechnology as an important tool for achieving food security goals. She said, ***"Africa's capacity to feed itself now and in the future requires increasing investments in climate change research, biotechnology research and development, and innovation."***

Kenya's Deputy President William Ruto reiterated government's commitment to remove the temporary ban on GM imports in order to allow commercialization of Bt cotton. He also stressed on the use of modern technology to assist in reduction of food costs – a big nightmare for most farmers. Furthermore, the Council of Governors on Health and Biotechnology through their chairman Jacktone Ranguma, called for immediate unconditional lifting of the ban on importation of genetically modified foods saying it was blocking biotechnology development in the country. The Kenyan Governors called for full implementation of the National Biotechnology Development Policy of 2006 and the operationalization of the Biosafety Act of 2009.

The Minister for Agriculture in Nigeria, Akinwunmi Adesina acknowledged the role of science and biotechnology in food production. He said: ***"We must not be afraid of science. We can use science to make our food safe, and on the issue of food security, we must be aware that technology is the only way we can open up opportunities. Also, we have to understand the risks and put good regulations in place to reduce those risks."*** The country stepped up efforts to getting the Biosafety Bill earlier approved by the parliament to receive presidential assent.

In January 2014, nearly one year after the President of Burkina Faso signed the amended biosafety law in February 2013, the National Biosafety Agency (NBA) started the process of registering the agency as a scientific and technical public institution. It will be transformed into a technical and scientific public organization (EPSET) in order to be administratively independent, allowing it to take sovereign decisions and better manage administrative tasks among government institutions. All the necessary documentation was sent to parliament for adoption including twenty legal texts. The revisions make implementation and enforcement of the legislation more practical than before and takes into consideration the needs and concerns of all key players. The country also built a national biosafety laboratory which has been equipped with new state-of-art equipment.

In Mozambique, the Council of Ministers approved a revised biosafety decree and biosafety implementing regulations to allow for biotech research and field trials for eventual commercialization. Candidate crops are drought-tolerant maize under the Water Efficient Maize for Africa (WEMA) and Bt cowpea.

While responding to claims that the Biosafety Bill in Uganda had been suspended, the State Minister for Finance Matia Kasaija reiterated the government's commitment to get the bill debated and passed. The Ugandan National Biotechnology and Biosafety Bill 2012 provides for a regulatory framework for the development and general release of Genetically Modified Organisms (GMOs).

Ethiopia's State Minister, Ministry of Environment and Forest Kare Chawecha acknowledged the important role of considering all technologies for posterity. He said: ***"Despite the controversies, we recognize that biotechnology issues, notably GMOs are not to go away. Even in countries where GMOs have become sensitive and emotional issues, it may not be possible to sideline the issues any longer. The trend is that the issues will keep on coming because GM products are already in our food chains and trade. Therefore, we have to rise above the ideological divide and work in partnership towards what is rational and beneficial to our common future."***

African farmers continued with their call for access to the technology for competiveness either through their leaders or individually.

A Zimbabwean legislator Samuel Sipepa Nkomo of the Movement of Democratic Change (MDC-T) said government's rigidity on GMOs was uncalled for as scientists from Zimbabwe had proved they were harmless. ***"Farmers are abandoning cotton because of prudence in policies by government, and who will die in Zimbabwe for using Bt cotton?"*** Nkomo asked. ***"Why are you so rigid to the extent you are not even allowing trials? You should allow for stakeholder discussions over the issue so that Zimbabweans decide on what they want,"*** he said.

In Swaziland, the Minister for Tourism and Environmental Affairs Jabulani Mabuza challenged local farmers to grow biotech crops in order to increase their yield and income. He said: ***"I encourage Swazis to learn more about biotech crops and apply it when it gets commercialized in the country."***

Progress was also reported on regional initiatives towards harmonization of policies and regulatory frameworks to allow for cost-efficiency in the sharing of knowledge, expertise and resources. In February 2014, the COMESA Council of Minsters approved the regional policy on Biotechnology and Biosafety, which had earlier on been endorsed by the fifth Joint meeting of the Ministers of Agriculture, Environment and Natural Resources in Addis Ababa in 2013. This follows more than ten years of continued work towards the development of the Regional Approach to Biotechnology and Biosafety Policy in Eastern and Southern Africa (RABESA). The Policy provides COMESA Member States with a mechanism for scientific regional risk assessment of GMOs intended for commercial planting, trade and access to emergency food aid with GM content in the COMESA region.

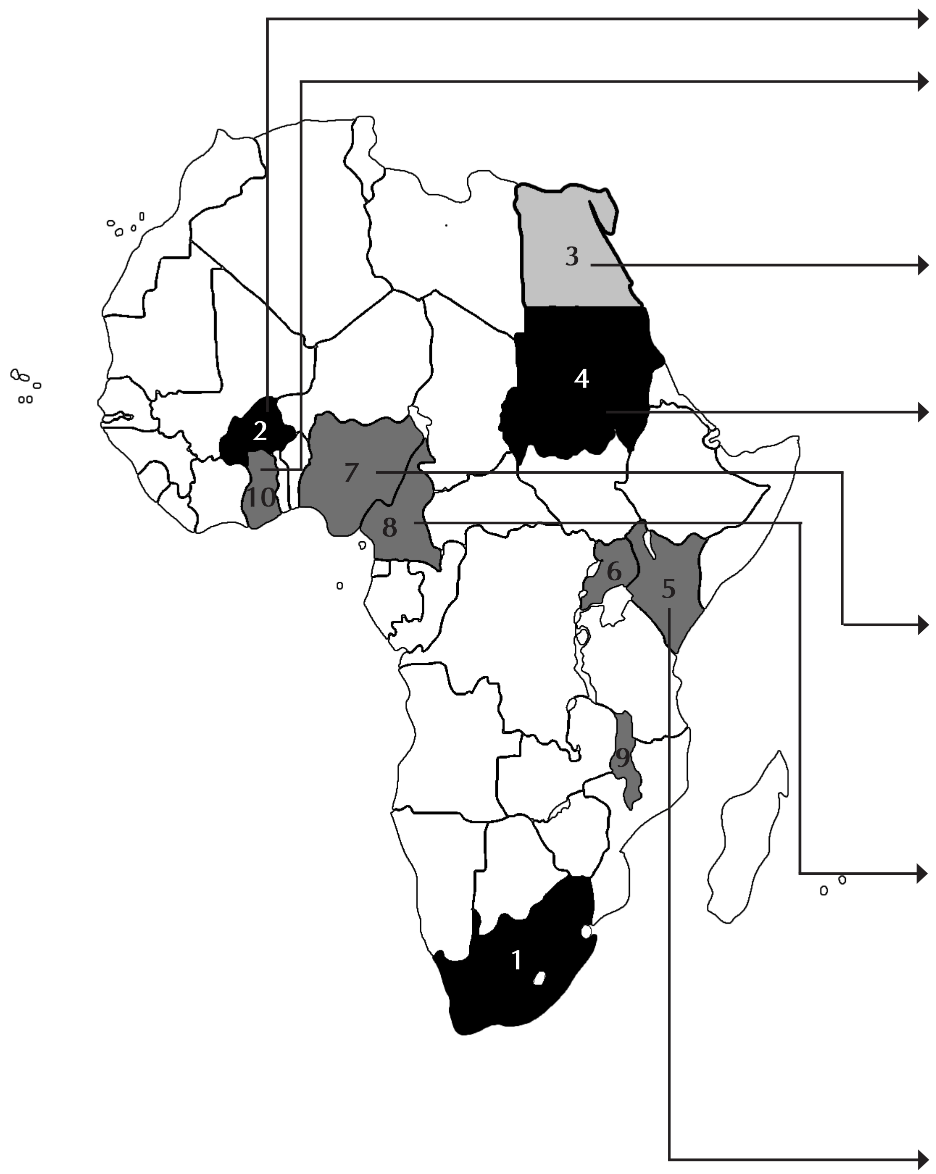
In West Africa, three regional organizations Permanent Inter-State Committee for Drought Control in the Sahel (CILSS), West African Economic and Monetary Union (WAEMU), and Economic Community of West African States (ECOWAS) have been working to harmonize their positions pertaining to a regional biosafety law. Discordance was mainly on the repair and reparation in case of damage, and on intellectual property. After two years of discussions, the organizations finally met in Bamako and arrived at a consensus in July, 2014. The Law will be readjusted accordingly and adopted by the three entities. The process is expected to be completed by December 2014, with ECOWAS as the likely implementing body.

The aforementioned progress notwithstanding, a number of challenges were experienced in 2014 with a bearing on the development pace and political goodwill for biotech crops in the continent. Gross misinformation was cited as the first key challenge posing great danger to acceptance of crop biotechnology. Tanzania's Deputy Finance Minister, Adan Malima urged experts to seek avenues like the media to educate the public on the subject warning that ***"Some people are sending wrong messages on these new technologies with false claims that they may cause male impotence, deformed bodies and cancer amongst many other wild allegations.***

The second challenge is the prolonged (2012) import suspension of GM produce for example in Kenya and Egypt, slowing down the stipulated timelines of getting Bt cotton commercialized by 2014 (Kenya) and expansion of Bt corn growing in Egypt. To date, the application for environmental release has not been submitted to the Kenyan National Biosafety Authority for review, while Egyptian farmers have missed out on two years of planting Bt corn maize.

The third challenge is the increased activism against the technology, which continues to put unnecessary burden to the regulatory process. It is imperative that the issues are urgently addressed to avert further

Figure 31. On-going Biotech/GM Crops Research Activities in Africa by October 22nd 2014



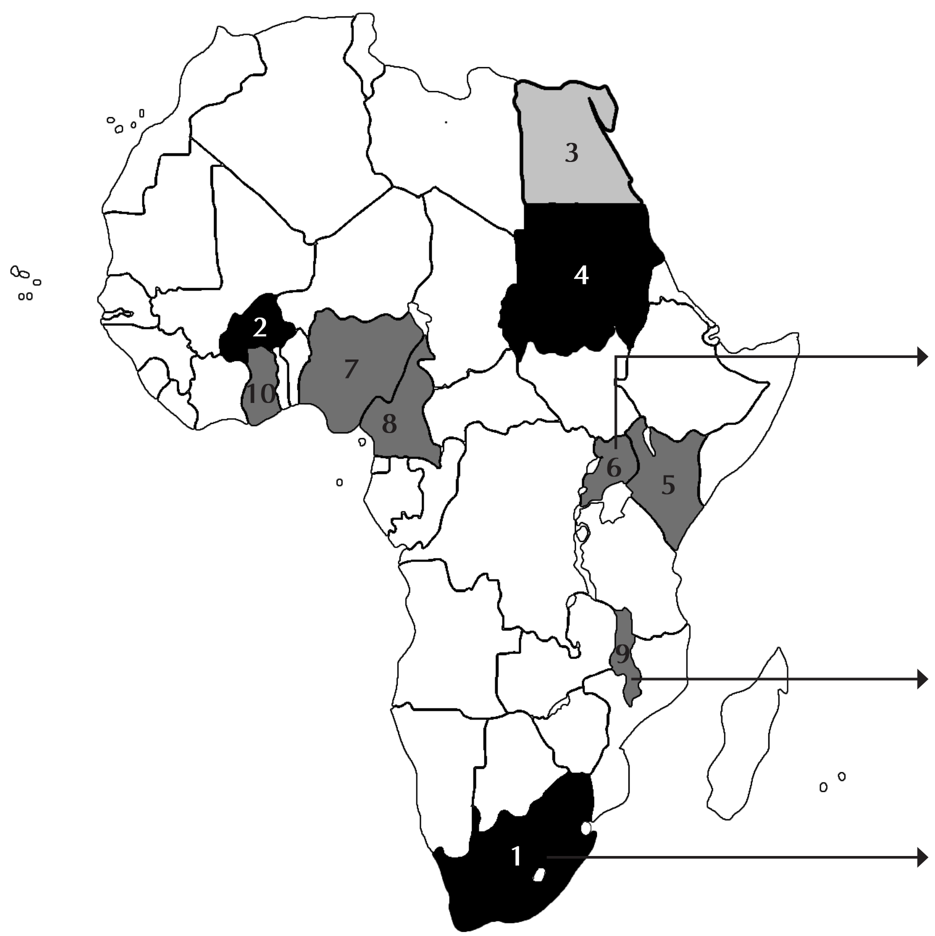
1, 2, and 4: Countries with commercialized GM crops and on going trials

5, 6, 7, 8, 9 & 10: Countries with on going trials

3: Planting put on hold but trials on going

Status of CFTs by October 2014				
Country	**Crop**	**Trait**	**Institutions Involved**	**Stage as of October 2014**
Burkina Faso	Cowpea, *Vigna unguiculata*	Insect resistance	INERA, AATF, NGICA, CSIRO	Multi-location trials in 2 sites
Ghana	Bt Cotton (Bollgard II)	Insect resistance Herbicide tolerant	Savannah Agricultural Research Institute	
	NUWEST rice	Nitrogen Use Efficiency/Water Use Efficiency and Salt Tolerance	AATF, Crops Research Institute	2nd CFT
	Bt Cowpea	Insect resistance	AATF, Savannah Agricultural Research Institute	2nd CFT
Egypt	Wheat, *Triticum durum* L.	Drought tolerant/salt tolerant	AGERI	CFT approved by NBC in 2010; extended in 2014
		Fungal resistance	AGERI	3rd season approved by NBC in 2010; extended in 2014
	Maize	Insect resistance	AGERI	CFT approved
Sudan 3rd year Bt cotton commercialized	Cotton, *Gossypium hirsutum* L.	Insect resistance	Biotechnology and Biosafety Research Center	3rd year Bt cotton commercialized
Nigeria	Cassava	Biofortified with increased level of beta-carotene, provitamin A	National Root Crops Research Institute	CFT 2nd season completed
	Cowpea	Insect resistant against Maruca pest	AATF, Institute of Agricultural Research	2nd season multi-locational trials in 3 sites
	Sorghum (ABS)	Biofortification	Africa Harvest, Pioneer Hi-Bred, a company of DuPont business, IAR and NABDA	4th CFT and back crossing with preferred Nigerian varieties
	Rice	Nitrogen use, Water efficient and salt tolerant (NUWEST) Rice	AATF, National Cereals Research Institute, Badeggi	Permit granted to commence trial in 2014
	Cassava	Cassava resistant to African cassava mosaic virus (ACMV) and Cassava brown streak virus (CBSV)	National Root Crops Research Institute , Umudike	Permit granted to commence trial in 2014
Cameroon	Cotton	Insect resistance and Herbicide tolerant	Bayer	3rd season CFT in multi-locations, in 3 sites
Kenya	Maize, *Zea mays* L.	Drought Tolerance (WEMA)	AATF, CIMMYT, KALRO	CFT - 6th season ongoing
		Insect resistance	AATF, CIMMYT, KALRO	CFT - 3rd season ongoing
	Cotton, *Gossypium hirsutum* L.	Insect resistance	KALRO, Monsanto	CFTs completed; Awaiting submission of application for commercial release
	Cassava, *Manihot esculenta Crantz*	Cassava mosaic disease	KALRO, Danforth Plant Science Center (DDPSC), IITA	CFT - 1st season completed
		Cassava Brown Streak Disease	KALRO, Danforth Plant Science Center (DDPSC), IITA,	CFT - 1st season completed
		Vitamin A enriched	KALRO, Danforth Plant Science Center (DDPSC)	CFT - 1st season completed
		Cassava Brown streak virus and cassava mosaic virus	Masinde Muliro University of Science and Technology (MMUST)	CFT - 1st season ongoing
	Sweetpotato, *Ipomoea batatas*	Sweetpotato virus disease	KALRO, Danforth Plant Science Center (DDPSC)	CFT - approved by NBA; Mock trials successfully completed
	Sorghum (ABS), *Sorghum bicolor Moench*	Enhanced Vit A levels, Bioavailable Zinc and Iron	Africa Harvest, Pioneer Hi-Bred, a DuPont business and KALRO	CFT - 5th season ongoing

Figure 31. On-going Biotech/GM Crops Research Activities in Africa by October 22nd 2014



1, 2, and 4: Countries with commercialized GM crops and on going trials

5, 6, 7, 8, 9 & 10: Countries with on going trials

3: Planting put on hold but trials on going

Status of CFTs by October 2014				
Country	**Crop**	**Trait**	**Institutions Involved**	**Stage as of October 2014**
Uganda	Maize, *Zea mays L.*	Drought tolerance	NARO, AATF, Monsanto, CIMMYT	CFT, 5th season planted
		Insect resistance	NARO, AATF, Monsanto, CIMMYT	CFT - 2nd season harvested in May 2014
	Banana, *Musa spp.*	Bacterial wilt resistance	NARO, AATF, IITA	CFT - 1st trial of 60 lines harvested, repeat trial planted on 14th September with 10 selected lines
		Nutrition enhancement (Fe and Pro-vitamin A)	NARO, QUT (Queensland University of Technology)	Harvested (one ratoon), conducting 3rd season
		Banana parasitic nematode resistance	NARO, University of Leeds	CFT – planted in August
	Cassava, *Manihot esculenta Crantz*	Virus resistance	NARO, DDPSC, IITA	CFT - 3rd season
		Cassava brown streak virus (CBSV) resistance	NARO, DDPSC, IITA	Multi location CFT application submitted to IBC/NBC
	NEWEST Rice	Nitrogen Use Efficiency/Water Use Efficiency and Salt Tolerance	NARO, AATF, Arcadia Biosciences	1st CFT harvested in September, importation of the second season planting seed on going
	Sweet Potato	Insect resistance	NARO, DDPSC, CIP	2nd season planting undertaken in September
Malawi	Cotton, *Gossypium hirsutum L.*	Insect resistance (Bt)	Bunda University, Monsanto, Ministry of Agric Envi. Affairs Dept National Commission for S&T	2nd season CFT for Bt Cotton harvested at Bunda College; 1st year multi-location CFTs for Bt cotton harvested; Application for environmental trait release submitted
South Africa	Maize, *Zea mays* L.	Drought tolerance	Monsanto	Multi-location CFT at 4 sites/3 extension permits issued
		Male fertility/pollen infertility	Pioneer	Multi-location CFT at 3 sites/4th year
		Insect resistance/herbicide tolerance IR/HT	Dow AgroScience	Multi-location CFT planted at 4 sites
		Insect resistance/herbicide tolerance IR/HT	Pioneer	Multi-location CFT at 4 sites/New and with extension permits: 1st, 3rd, 4th & 5th years
	Cotton, *Gossypium hirsutum* L.	Insect resistance/herbicide tolerance IR/HT	Bayer	CFT at one site repeat/5th year
	Soybean	Modified oils/fatty acids HT	Pioneer	CFT planted at 3 sites

delay of safe and beneficial crop technologies to African farmers who need them most.

Key Agri-biotech developments in Africa as captured in the Crop Biotech Update (September 2013 – September 2014)

EGYPT

The Faculty of Agriculture at Cairo University in collaboration with Colorado State University (CSU) initiated a program to explore opportunities for academic and research collaboration. The collaboration would also include Hawassa University in Ethiopia and University of Nairobi in Kenya. The program will comprise activities covering topics such as water resources and water management, GMO and biosafety, plant breeding for drought tolerant plants, precision agriculture and biofuels (Crop Biotech Update, 28 May 2014).

ETHIOPIA

Leading scientists from across the African continent called on the continent leadership to adopt biotechnology for development in a declaration of the 9th Annual Meeting of the African Science Academies in Addis Ababa, Ethiopia. The main objective of the meeting was to urge African leaders to play a leading role in the continent's biotechnology revolution (Crop Biotech Update, 11 September 2013).

The Ethiopian Institute of Agricultural Research (EIAR) and the International Institute of Tropical Agriculture (IITA) launched a new project to develop disease resistant Enset through biotechnology in December 2013. The Enset or the Ethiopian banana (Ensete ventricosum) is a staple food source for over 15 million people in Ethiopia, which has been affected by a deadly bacterial disease since 1968 (Crop Biotech Update, 18 September 2013).

GHANA

Cotton farmers in Ghana called for the speedy adoption of Bt cotton to revamp cotton production in the country. The farmers decried the fact that they were lagging behind compared to their counterparts in Burkina Faso (Crop Biotech Update, 4 December 2013).

Ghana's Deputy Minister for Trade and Industry Nii Lantey Vanderpuye reaffirmed the commitment of his government to introduce Bt cotton farming. The Minister noted the government's concern on the country's low cotton production, which is well below potential and how it (government) had identified introduction of Bt cotton as one of the strategies for revamping the sector (Crop Biotech Update, 4 December 2013).

Ghana's Minister for Environment, Science, Technology and Innovation, Joe Oteng-Adjei, stated that the country was in the process of adopting genetic modification (GM) technology to improve agricultural production and income for farmers. Dr. Oteng-Adjei said with the passage of the Biosafety and Biotechnology Law, Ghana had a good case to adopt the GMO innovation to enhance agricultural production through scientific methods (Crop Biotech Update, 4 December 2013).

KENYA

The Bill and Melinda Gates Foundation (BMGF) donated US$1.2 million to set up a maize research facility designed to reduce the time period of development of varieties that are resistant to viral maize lethal necrosis (MLN). The facility is expected to serve as a hub to train young researchers and students in Africa on MLN screening and identification of MLN-resistant maize germplasm (Crop Biotech Update, 4 September 2014).

Biotechnology stakeholders in Kenya formally petitioned a government taskforce set up to review GMO food safety to urgently lift the ban on GM food imports. The stakeholders presented these views during a public hearing held in Nairobi on 25 April 2014. The taskforce was expected to utilize the views submitted to prepare a report with recommendations on how the Government of Kenya should proceed with regards to the GM technology. Stakeholders have maintained that the ban, which was imposed by the Ministry of Public Health in November 2012, was based on misinformation about the safety of GM foods and is stifling research, denying farmers' access to new biotech tools and scaring away investors in the sector (Crop Biotech Update, 30 April 2014).

The chairman of the Council of Kenyan Governors on Health and Biotechnology, Governor Jack Ranguma called on the government to lift the ban on imports of genetically modified foods. The Governor argued that the ban on GM food was rushed and the country was sending mixed signals to investors who are eager to invest in the country. Giving his experience on his visit to Burkina Faso, he acknowledged the potential of biotech crops in preserving the environment through reduced spraying (Crop Biotech Update, 11 June 2014).

LIBERIA

The Central Agricultural Research Institute (CARI) in Suakoko District, Bong County in the northern central Liberia, finalized plans to re-establish a biotechnology center at the institute as part of its operation to make Liberia self-sufficient in food production. The center was re-established to utilize biological processes to purely modify living organisms for specific uses at CARI and the country at large (Crop Biotech Update, 6 November 2013).

NIGERIA

Nigeria's Minister for Agriculture and Rural Development, Dr Akinwumi Adesina called for acceleration of adoption of biotechnology in Africa. Adesina said this when he delivered the keynote address during the breakfast session at the World Food Prize lecture series in Des Moines, Iowa, USA. He also noted that biotechnology provides a way to feed the world with more nutritious food, while depending less on chemicals (Crop Biotech Update, 6 November 2013).

Nigeria's supervising Minister for Science and Technology, Mrs. Omobola Johnson, urged biotech stakeholders in the country not to relent in advocating for establishment of a Biosafety Law. She noted that this would ensure Nigerians reap the benefits of modern biotechnology similar to the rest of the world. She added that the role of agricultural biotechnology in tackling food insecurity, spurring youth employment and enhancing socioeconomic development cannot be overemphasized (Crop Biotech Update, 30 April 2014).

SWAZILAND

The Swaziland Minister for Tourism and Environmental Affairs, Mr Jabulani Mabuza challenged local farmers to grow biotech crops to increase their yield and income. He encouraged Swazis to learn more about biotech crops and apply the technology when commercialized in their country. The Swaziland

Cotton Board has already filed an application for field trials with the Swaziland Environment Authority (SEA). The National Biosafety Advisory Committee (NBAC) has been reviewing the application to conduct confined field trials on the verge of finalizing the review and assessment of sites where the trials will be conducted (Crop Biotech Update, 3 September 2014).

TANZANIA

The Tanzanian Deputy Minister for Finance, Mr Adam Malima deplored the slow adoption of agri-biotech in Tanzania due to lack of trained staff, infrastructure for biotech research, regulatory hurdles and public knowledge on biotech. He said that despite numerous efforts made by the government in collaboration with stakeholders to educate the public on the use of modern biotechnology, there is still limited knowledge amongst the public (Crop Biotech Update, 25 June 2014).

TOGO and BENIN

Policy makers, regulators, and farmers from Togo and Benin visited Burkina Faso's Bt cotton fields to learn about the benefits farmers have realized from Bt cotton farming. The Government of Togo is revising its Biosafety law, whereas Benin lifted a moratorium on GM products and both countries are interested in introducing Bt cotton in the near future (Crop Biotech Update, 8 January 2014).

UGANDA

The Biosciences Information Center was launched 12 September 2013 by the Uganda's National Agricultural Research Organization The Center is hosted at the National Crop Resources Research Institute (NaCRRI), Namulonge and is also part of ISAAA's global network of Biotech Information Centers (Crop Biotech Update, 18 September 2013).

ZAMBIA

The Cotton Board of Zambia, through its secretary Dafulin Kaonga called on the Government to use genetic engineering to sustain the production of cotton and other crops in Zambia. He asked the Government to consider investing in capacity development in modern biotechnology. Once the human resource base and infrastructure is adequate, the country would be able to develop its own genetically modified crops which will be available to farmers at a lower cost. He added that Kaonga-Zambia should work with partners including biotechnology companies and farmers in developing genetically modified cotton (Crop Biotech Update, 30 April 2014).

ZIMBABWE

Zimbabwean farmers called for the adoption of Bt cotton to increase production and revive the textile and clothing industry in their country. After a visit to the Bt cotton trial in Malawi, Berean Mukwende of the Zimbabwe Farmers Union said that the Zimbabwean farmers are experiencing massive losses because of bollworm infestation. He advocated for Bt cotton as a possible solution to bollworm infestation and a means to enhance the profit of farmers (Crop Biotech Update, 10 April 2014).

Zimbabwe's National Biotechnology Authority CEO, Jonathan Mufandaedza, told the Parliamentary committee on lands, agricultural mechanization and irrigation that Zimbabwe should adopt Bt cotton because of its resistance to pests and potential to yield more. He said that documentary evidence from countries like Burkina Faso shows that Bt cotton seeds increase yield by 24 percent (Crop Biotech Update, 13 August 2014).

African Development Bank (AfDB)

The African Development Bank (AfDB) donated US$63 M to research companies in Africa to help them undertake projects aimed at boosting the continent's agricultural production. Freddie Kwesiga, the AfDB's representative in Zambia, stated that science-based agriculture was vital in strengthening food security across the continent, thus the development bank had issued funding in Africa to conduct research in order to enhance production. Kwesiga added that researches are being conducted on various crops that do not mainly depend on the level of rainfall such as soybean to boost production and enhance food security in the continent (Crop Biotech Update, 16 October 2013).

The African Development Bank (AfDB) and the International Food Policy Research Institute (IFPRI) advocated for embracement of agricultural innovations in Africa to better compete in an evolving global bio-economy. This was in a report launched in September 2014, entitled "GM Agriculture Technologies for Africa," which provided a comprehensive analysis of the benefits and constraints of adopting genetically modified (GM) technologies to address challenges related to population, poverty, food insecurity and climate change (AfDB, 30 September 2014).

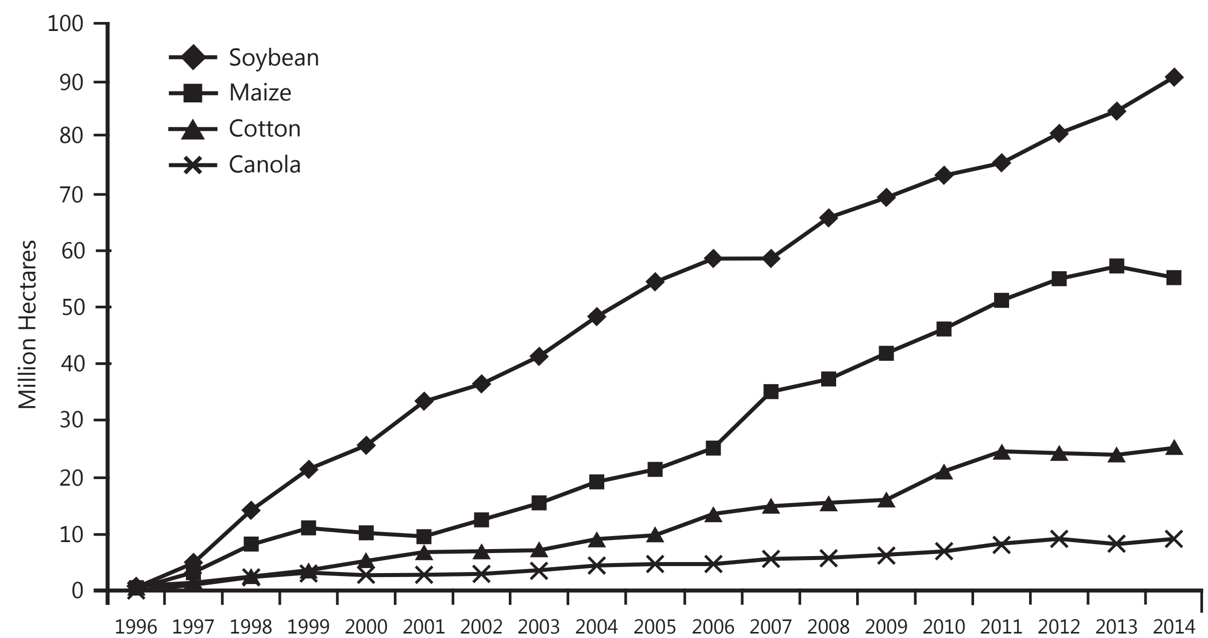
COMESA

After more than 10 years of continued work towards the development of the Regional Approach to Biotechnology and Biosafety Policy in Eastern and Southern Africa (RABESA), the proposed guidelines were adopted by the 32nd Meeting of the COMESA Council of Ministers in February 2014, as the COMESA Policy on Biotechnology and Biosafety (Crop Biotech Update, 10 September 2014).

Distribution of Biotech Crops, by Crop

The distribution of the global biotech crop area for the four major crops is illustrated in Figure 32 and Table 42 for the period 1996 to 2014. It clearly shows the continuing dominance of biotech soybean occupying 50% of the global area of biotech crops in 2014. With the exception of about 5.8 million hectares of the stacked soybean (HT/Bt) in four countries in Latin America (Brazil Argentina, Paraguay and Uruguay), the entire biotech soybean hectarage is herbicide tolerant. As predicted in ISAAA Brief 46 for 2013 the stacked soybean product HT/Bt penetrated deeply in 2014 into tropical areas of four countries in South America. Biotech soybean retained its position in 2014 as being by far the biotech crop occupying the largest area globally, at 90.7 million hectares in 2014, 7% higher than the 84.5 million hectares in 2013. Biotech maize had the second largest area at 55.2 million hectares, with decrease in hectarage of 2.1 million hectares, due to farmers shifting from maize to soybean. Upland biotech cotton reached 25.1 million hectares in 2014 up from the 23.9 million hectares grown in 2013. Canola reached 9 million hectares in 2014, up 10% compared with 8.2 million hectares in 2013. Sugar beet was first commercialized in the USA and Canada in 2007, and quickly plateaued at a high adoption rate of 96% in 2011, 2012 and 2013 and 98.5% in 2014. HT sugar beet has had the fastest adoption rate of any biotech crop. 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; this was equivalent to approximately 15% of the 1.3 million hectares seeded in the USA in 2011. In 2012, another estimated 225,000 hectares were planted for a total of 425,000 hectares and again 325,000 hectares in 2013. In 2014, it is estimated that

Figure 32. Global Area of Biotech Crops, 1996 to 2014: by Crop (Million Hectares)



Source: Clive James, 2014.

Table 42. Global Area of Biotech Crops, 2013 and 2014: by Crop (Million Hectares)

Crop	2013	%	2014	%	+/-	%
Soybean	84.5	48	90.7	50	+6.2	+7
Maize	57.3	33	55.2	30	-2.1	- 4
Cotton	23.9	14	25.1	14	+1.2	+ 5
Canola	8.2	5	9.0	5	+0.8	+ 10
Sugar beet	0.5	>1	0.5	<1	—	—
Alfalfa	0.8	>1	0.9	1	+0.1	+ 13
Papaya	>0.1	>1	>0.1	<1	<0.1	—
Others	>0.1	>1	<0.1	<1	<0.1	—
Total	**175.2**	**100**	**181.5**	**100**	**+6.3**	**+ 3 to 4**

Source: Clive James, 2014.

there was up to an accumulated 862,000 hectares of herbicide tolerant alfalfa in the US. This is likely to increase in the near term as the newly-approved reduced lignin alfalfa is commercialized in 2015. Small hectarages (1,000 hectares each) of biotech virus-resistant squash, papaya and sweet corn continued to be grown in the USA. China also grew a total of 8,475 hectares of biotech papaya in 2014, a 46% increase from 5,000 hectares in 2013. Guangxi province planted its first biotech papaya in 2014 at 2,000 hectares, with a 90% adoption rate. A total of 543 hectares of Bt poplar were planted in China.

Biotech soybean

In 2014, biotech soybean accounted for 50% of all the biotech crop hectarage in the world and was grown in 11 countries. The global hectarage of HT and HT/IR soybean in 2014 was 90.7 million hectares, up by a record 6.2 million hectares, or 7% from 2013 at 84.5 million hectares. The increase resulted from higher adoption in the US and Brazil, followed by Canada, Paraguay and Uruguay. Modest increases were recorded in South Africa where adoption is 92%. Of the 11 countries which reported growing biotech soybean in 2014, the top three countries growing by far the largest hectarage of herbicide tolerant and HT/Bt soybean were the USA (32.3 million hectares), Brazil (29.07 million hectares) and Argentina (20.8 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 111 million hectares of soybean grown in 2014 (FAO 2014), an impressive 82% or 90.7 million hectares were RR®soybean and HT/IR soybean.

Provisionally, the increase in income benefits for farmers growing biotech soybean during the 18-year period 1996 to 2013 was US$41.7 billion and for 2013 alone, US$5.6 billion (Brookes and Barfoot, 2015, Forthcoming).

Biotech maize

In 2014, 55.2 million hectares of biotech maize were planted – this represents a decrease of 4%, equivalent to 2.1 million hectares. The reduced planting is mainly due to a 4% decreased planting in the US with several other countries also decreasing maize hectarage marginally in favor of the less demanding soybean. It is noteworthy that 17 countries grew biotech maize in 2014. There were five countries which grew more than 1 million hectares of biotech maize in 2014 in decreasing order of hectarage they were: USA (34.5 million hectares), Brazil (12.5 million), Argentina (3 million), South Africa (2 million) and Canada (1.4 million hectares). Modest increases were reported by several countries. Five EU countries continued to plant 143,016 hectares of biotech Bt maize in the EU in 2014, equivalent to a 3% decrease over 2013 of 148,013 hectares in five countries. The five countries, in decreasing order of hectarage were Spain, Portugal, Czechia, Romania and Slovakia. An important feature of biotech maize is stacking, which is discussed in the sections on countries and traits.

Of the global hectarage of 184 million hectares (FAO, 2014) of maize grown in 17 countries in 2014, 30% or 55.2 million hectares were biotech maize. 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 approximately 40% of total maize hectarage in 2014.

The provisional increase in income benefits for farmers growing biotech maize during the 18 years (1996 to 2013) was US$44.6 billion and US$9.4 billion for 2013 alone (Brookes and Barfoot, 2015, Forthcoming).

Biotech cotton

The area planted to biotech upland cotton globally in 2014 was 25.1 million hectares up from the 23.9 million hectares in 2013. A total of 15 countries grew biotech cotton in 2014 and four grew more than 1.0 million hectares, in descending order of hectarage, they were: India (11.6 million hectares), USA (4.3 million), China (3.9 million), Pakistan (2.9 million hectares). Another 11 countries grew biotech cotton in 2014, for a total of 15 countries.

RR®Flex cotton was introduced in the USA and Australia for the first time in 2006 and was widely grown in 2014. In 2014, biotech hybrid cotton in India, the largest cotton growing country in the world, occupied 11.6 million hectares of approved Bt cotton despite almost optimal levels of adoption which reached 95% in 2014. The advantages of Bt cotton hybrid in India are significant and the increase in 2014 was due to the significant gains in production, economic, environmental, health and social benefits, which have 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 to 247,000 hectares in 2011, over 300,000 hectares in 2012, 474,229 hectares in 2013, and 454,124 hectares in 2014, an adoption rate of 73.8% in 2014 compared to 68.6% in 2013. Australia planted only 200,000 hectares biotech cotton in 2014 at over 99% adoption rate after a peak hectarage of almost 600,000 hectares in 2011. Lack of water is the main element that determines the extent of cotton hectares in Australia; nevertheless, over 99% biotech adoption rate was maintained irrespective of the absolute hectarage of cotton. Based on a global hectarage of 37 million hectares (FAO, 2014), 68% or 25.1 million hectares, were biotech cotton and grown in 15 of the 28 biotech crop countries worldwide.

Provisionally, the increase in income benefits for farmers growing biotech cotton during the 18-year period 1996 to 2013 was US$42.2 billion and US$4.8 billion for 2013 alone (Brookes and Barfoot, 2015, Forthcoming).

Biotech canola

The global area of biotech canola is estimated to have increased by a significant 800,000 hectares from 8.2 million in 2013 to 9.0 million hectares in 2014, with most of the increase coming from Canada. The USA was also up about 200,000 and Australia was up by over 100,000 hectares. Canada, by far, is the largest grower of canola globally, and the adoption rate in 2014 continued to be high at 95%. Only four countries currently grow biotech canola: Canada, the USA, Australia and Chile. The global hectarage and prevalence of canola 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 is used for biodiesel; this is expected to remain low at around 2% until new biodiesel plants come on stream.

Of the global hectarage of 36 million hectares of canola grown in 2014, 25%, or 9 million hectares were biotech canola grown in Canada, the USA, Australia and Chile.

The provisional increase in income benefits for farmers growing biotech canola during the 18-year period 1996 to 2013 was US$4.3 billion and US$0.6 billion for 2013 alone (Brookes and Barfoot, 2015, 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 of alfalfa seeded in 2006. Herbicide tolerance is probably the first of several traits that will 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 accumulated RR®alfalfa in the USA in 2007 to 102,000 hectares. There are approximately 8 to 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 a perennial and may occupy more of a niche market. However, there are many observers who are convinced that at least half or more of the alfalfa in the USA could be RR®alfalfa by 2015 by which time there will also be other beneficial traits in the marketplace including low lignin alfalfa. After several court hearings, RR®alfalfa was cleared for planting in January 2011, and it was estimated that US hectarage of RR®alfalfa in 2011 was up to ~200,000 hectares (APHIS, 2011). It was estimated that another 225,000 hectares were seeded in 2012 for an estimated total of 425,000 hectares and an additional 325,000 hectares seeded in 2013 for a total of up to ~750,000 hectares or ~10% of national hectarage of alfalfa of 8 million hectares. In 2014, it is estimated that the total accumulated herbicide tolerant perennial crop seeded from 2011 to 2014 is up to 862,000 hectares.

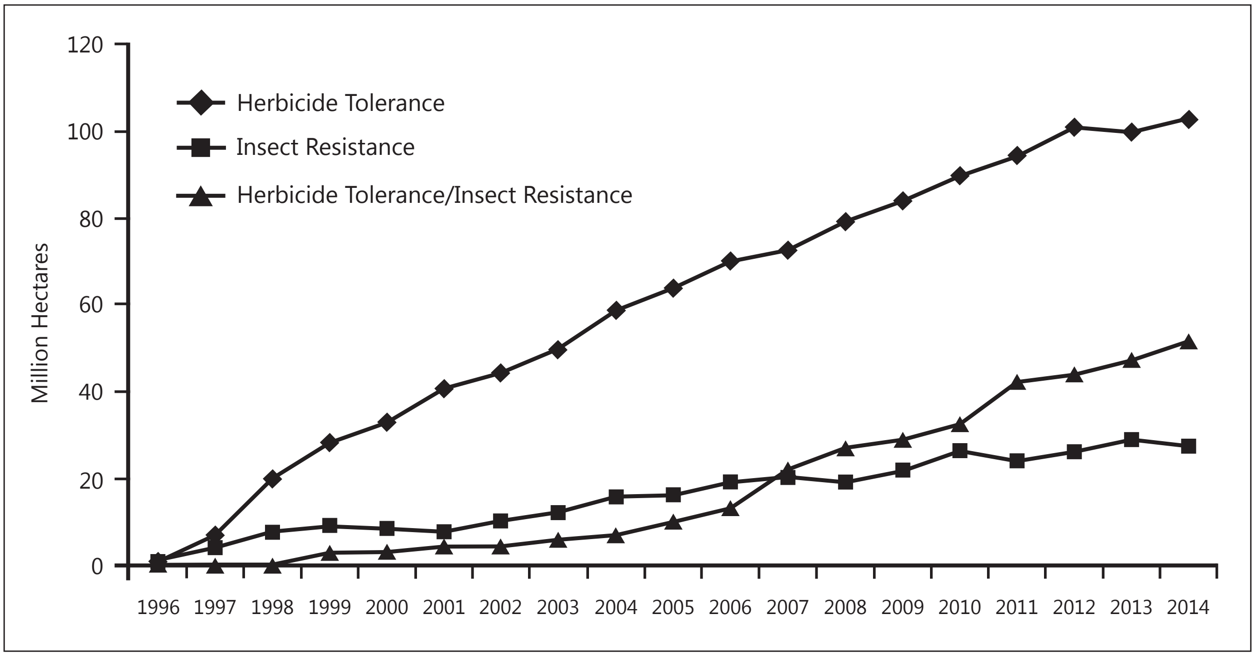
Unlike adoption rates for the principal crops of soybean maize and cotton, USDA does not publish adoption rates for biotech alfalfa – however observers familiar with the product are opining that it could reach up to 50% in the near term when the stacked HT/low lignin that offer higher digestibility will be an added benefit attractive to alfalfa growers. In 2014, biotech low-lignin alfalfa was approved for cultivation in the US, which dependent on seed supply, and other factors could be planted as early as 2015. The product, which has less lignin, has higher digestibility, and it is claimed to also offer a 15 to 20% increase in yield and hence is likely to be in high demand by farmers.

Other biotech crops
Biotech sweet corn is estimated to be at a minimal and nominal hectarage of 1,000 hectares of the sweet corn hectarage of an estimated 300,000 hectares. Small areas of biotech virus resistant squash (1,000 hectares) and PRSV resistant papaya in Hawaii (1,000 hectares) continued to be grown in the USA in 2014; the papaya industry in Hawaii was destroyed by PRSV and saved by the biotech papaya which is resistant to PRSV. In China in 2014, 8,475 hectares of biotech papaya were planted, a 46% increase from 5,000 hectares in 2013. Guangxi province planted their first biotech papaya in 2014 at 2000 hectares, a 90% adoption. A total of 543 hectares of Bt poplar were planted in China.

Distribution of Biotech Crops, by Trait

During the 19 year period 1996 to 2014, herbicide tolerance has consistently been the dominant trait (Figure 33). In 2014, herbicide tolerance, deployed in soybean, maize, canola, cotton, sugar beet and alfalfa occupied 102.6 million hectares or 57% of the 181.5 million hectares of biotech crops planted globally (Table 43); this compares with 99.4 million hectares equivalent to 57% adoption of the total

Figure 33. Global Area of Biotech Crops, 1996 to 2014: by Trait (Million Hectares)



Source: Clive James, 2014.

Table 43. Global Area of Biotech Crops, 2013 and 2014: by Trait (Million Hectares)

Trait	2013	%	2014	%	+/-	%
Herbicide tolerance	99.4	57	102.6	57	+3.2	+ 3
Stacked traits	47.1	27	51.4	28	+4.3	+ 9
Insect resistance (Bt)	28.8	16	27.4	15	-1.4	– 5
Virus resistance/Other	<1	—	<1	—	+0.2	—
Total	**175.2**	**100**	**181.5**	**100**	**6.3**	**+3 to 4**

Source: Clive James, 2014.

biotech hectarage in 2013. Thus, herbicide tolerance increased by a net 3.2 million hectares from 99.4 million hectares in 2013 to 102.6 million hectares in 2014. The major contribution to this was a 3 million hectare increase in the US; which was offset by a significant substitution in Brazil of herbicide tolerant soybean by the stacked product HT/Bt (5.2 million hectares in 2014); an increase of 0.3 million hectares of HT canola in Canada; and a smaller increase of ~200,000 hectares HT canola in the US.

Stacked traits are favored by farmers in all countries for all crops and soybean is no different. Stacked traits increased from 47.1 million hectares in 2013 to 51.4 million hectares in 2014 – an increase of 4.3 million hectares equivalent to a 9% increase from 2013 to 2014. Hectarage featuring insect resistance decreased from 28.8 million by 5% to 27.4 million hectares in 2014; a decrease in Bt cotton in China contributed to this smaller hectarage. Generally, the increases and decreases for various traits were mainly due to changes in the key countries of the USA, Brazil, Canada, India and China, in addition, countries like Paraguay and Uruguay continued to report modest but steady growth. The stacked traits for herbicide tolerance and insect resistance are deployed in cotton and soybean (Bt/HT), maize (Bt/Bt/IR, Bt/HT, and Bt/Bt/HT) but not in sugar beet and alfalfa. The Bt/Bt/IR stack refers to different Bt or other IR genes that code for different insect resistant traits, for example for maize, above ground pests and below ground pests and herbicide tolerance are all stacked in the same maize product. In terms of year-over-year increases, the highest growth was for stacked traits at 9%, followed by herbicide tolerance at 3% with insect resistance recording a decrease of 5%, most of which was the net result of significant decreases in Bt maize in Brazil followed by the US, plus a decrease in Bt cotton in China and offset by increases in Bt cotton in India and smaller shifts in other countries.

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™ comprising 8 genes coding for three traits, launched in the USA and Canada in 2010.

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 two thirds (62%) of the 51.4 million hectares "stacked traits" in 2014. The relative percentage in the US is expected to decline proportionally over time as leading emerging developing countries like Brazil plant more stacks generally and when new stack products like HT/Bt soybean become available and adopted. Adoption of HT/Bt in Brazil and neighboring countries increased very rapidly to 5.2 million hectares. In 2014, the other nine principal countries, of a total of 13, which deployed stacked traits were: Brazil (12.6 million hectares), Argentina (2.6), South Africa (1.2), Canada (1.1), Philippines (0.76), Paraguay (0.5), Uruguay (0.4), Australia (0.2 million hectares), and Mexico (0.2 million hectares). Colombia, Honduras, and Chile 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.

To-date, the Bt genes have made a herculean contribution to conferring resistance to a broad range of insect pests in some of the major crops, including maize (the highest figure for all crops), cotton, and important pro-poor vegetables such as eggplant. Both industrial countries like the US or Canada, as well as poor countries like Burkina Faso and Bangladesh have benefited from Bt genes and the potentials for the future is enormous.

Entomologist Dr. Anthony M. Shelton from Cornell University shares his views on insect resistance trait through the Bt gene (AM Shelton, 2013, 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 provisional economic benefits at the farm level by trait, for the first eighteen years of commercialization of biotech crops 1996 to 2013 was as follows: all herbicide tolerant crops at US$54.9 billion and all insect resistant crops at US$78.1 billion, with the balance of US$0.3 billion for other minor biotech crops. For 2013 alone, the benefits were: all herbicide tolerant crops US$7.9 billion, and all insect resistant crops US$12.48 billion plus a balance of US$0.02 billion for the minor biotech crops for a total of ~US$20.4 billion (Brookes and Barfoot, 2015, Forthcoming).

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 latest (FAO 2014, with latest 2013 data) respective global areas of the four principal crops – soybean, cotton, maize and canola – in which biotechnology is utilized (Table 44 and Figure 34). The data indicate that in 2014, 82% (90.7 million hectares) of the 111 million hectares of soybean planted globally (FAO, 2014) were biotech. Of the 37 million hectares of global cotton, 68% or 25.1 million hectares were biotech in 2014. Of the 184 million hectares of global maize planted in 2014 (FAO, 2014), almost one-third (30%) or 55.2 million hectares were biotech maize. Finally, of the 36 million hectares of canola (FAO, 2014) grown globally in 2014, 25% were herbicide tolerant biotech canola, equivalent to 9.0 million hectares. If the global areas (conventional plus biotech) of these four crops are aggregated, the total area is 368 million hectares, of which half, 49% or 181.5 million hectares, were biotech in 2014. These adoption figures should be viewed as "indication" of adoption, not as precise estimates of adoption globally for the four crops.

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 368 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.

Global Status of Regulatory Approvals

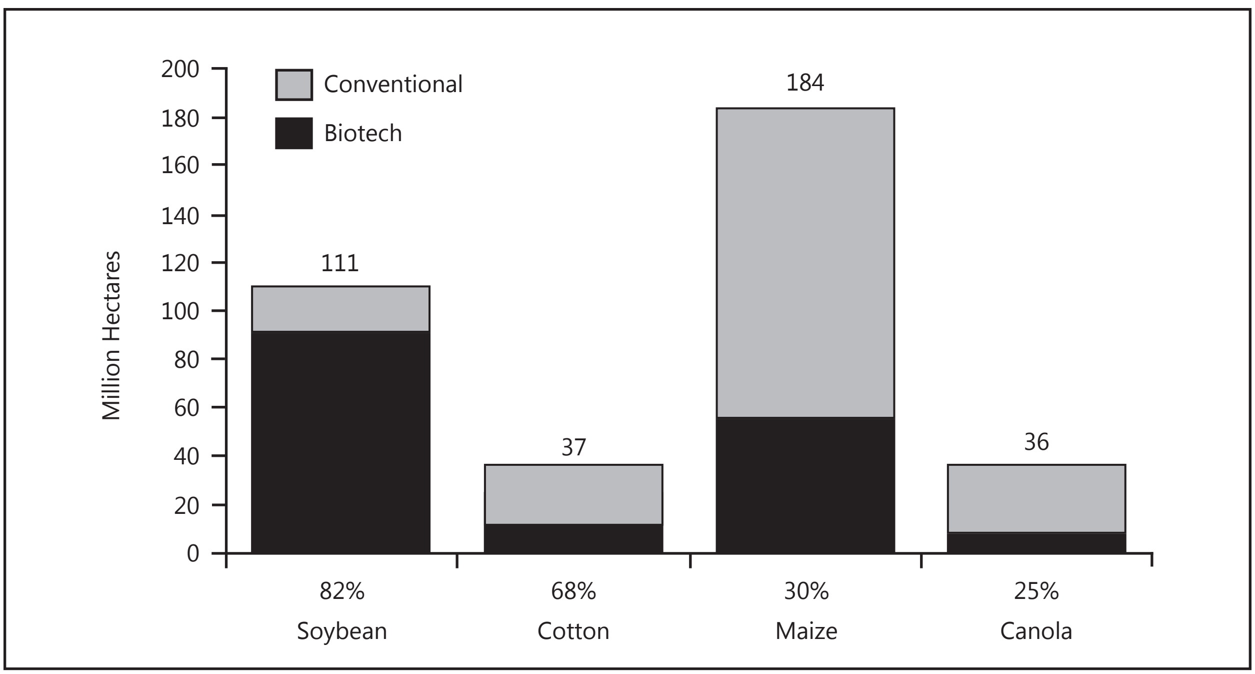
As of the end of October 2014, a total of 38 countries (37 + EU - 28) have granted regulatory approvals to biotech crops for use as food, feed or for environmental release since 1994. From these countries, 3,083 regulatory approvals have been issued by competent authorities across 27 GM crops and 357 GM events. 1,458 are for food use (direct use or for processing), 958 for feed use (direct use or for processing) and 667 for environmental release or planting. Japan has the most number of approved events (201), followed by the U.S.A. (171 not including stacked events), Canada (155), Mexico (144), South Korea (121), Australia (100), New Zealand (88), Taiwan (79), Philippines (75), European Union (73 including approvals that have expired or under renewal), Colombia (73), South Africa (57) and

Table 44. Biotech Crop Area as Percent of Global Area of Principal Crops, 2014 (Million Hectares)

Crop	Global Area*	Biotech Crop Area	Biotech Area as % of Global Area
Soybean	111	90.7	82
Cotton	37	25.1	68
Maize	184	55.2	30
Canola	36	9.0	25
Others	—	1.4	—
Total	**368**	**181.5**	**49**

Source: Compiled by ISAAA, 2014. *Latest FAO, 2013 (Global hectarage data for 2012)

Figure 34. Global Adoption Rates (%) for Principal Biotech Crops, 2014 (Million Hectares)



Global Hectarages Data for 2012 (FAO, 2013)
Source: Compiled by Clive James, 2014.

China (55). Maize still has the most number of events (136 events in 29 countries), followed by cotton (52 events in 21 countries), canola (32 events in 13 countries), potato (31 events in 10 countries), and soybean (30 events in 28 countries).

Among the GM events, the herbicide-tolerant soybean event GTS-40-3-2 has the most number of approvals (52 approvals in 26 countries + EU-28). It is followed by the herbicide-tolerant maize event NK603 (52 approvals in 25 countries + EU-28), insect-resistant maize MON810 (50 approvals in 25 countries + EU-28), insect resistant maize Bt11 (50 approvals in 24 countries + EU-28), insect-resistant maize TC1507 (47 approvals in 22 countries + EU-28), herbicide-tolerant maize GA21 (41 approvals in 20 countries + EU-28), insect-resistant cotton MON531 (39 approvals in 19 countries + EU-28), insect-resistant maize MON89034 (39 approvals in 22 countries + EU-28), herbicide-tolerant soybean A2704-12 (39 approvals in 22 countries + EU-28), insect-resistant maize MON88017 (37 approvals in 20 countries + EU-28), herbicide-tolerant maize T25 (37 approvals in 18 countries + EU-28) and insect-resistant cotton MON 1445 (37 approvals in 17 countries + EU-28).

The Global Value of the Biotech Crop Market

Global value of the biotech seed market alone was US$15.7 in 2014

In 2014, the global market value of biotech crops, estimated by Cropnosis is US$15.7 billion (up marginally from US$15.6 billion in 2013) (Table 45); this represents 22% of the US$72.3 billion global crop protection market in 2013, and 35% of the ~US$45 billion global commercial seed market (Appendix 3). The US$15.7 billion biotech crop market comprised: US$8.6 billion for biotech maize (equivalent to 55% of global biotech crop market, and down marginally from 8.9 billion or 56.5% in 2013); US$5.2 billion for biotech soybean, up 6.1% from 2013 and 33% of the global biotech crop market; US$1.2 billion for biotech cotton (7.5% of global), and US$0.4 billion for biotech canola (3% of global) and US$0.2 billion (1.5% of global) for sugar beet and others. Of the US$15.7 billion biotech crop market, US$11.3 billion (72%) was in the industrial countries and US$4.4 billion (28%) was in the developing countries. The market value 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 19 year period, since biotech crops were first commercialized in 1996, is estimated at US$133,541 million (Table 45).

A holistic estimate of the value of biotech crops globally and in the USA was 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

Table 45. The Global Value of the Biotech Crop Market, 1996 to 2014

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
2013	15,610
2014	**15,690**
Total	**133,541**

Source: Cropnosis, 2014 (Personal Communication).

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).

FUTURE CHALLENGES

Feeding the World of 2050

Feeding over 9 billion people in 2050 is one of, if not THE most daunting challenges facing mankind during the remaining years of this century. The fact that the majority of the world's population is not even aware of the magnitude of the challenge makes the task even more difficult. The following paragraphs chronicle some of the salient and critical facts in relation to the dimensions of feeding the world of 2050 and beyond.

- Global population, which was only 1.7 billion at the turn of the century in 1900, is now 7.2 billion, expected to climb to 9.6 billion by 2050, and will be close to 11 billion at the end of this century in 2100.
- Coincidentally, a change is occurring in favor of a less efficient higher protein diet, including significantly more meat in more prosperous developing countries led by China and India, where higher incomes will drive demands of a new and emerging global burgeoning 'middle class'.
- Need to increase crop productivity, the principal source of food, by at least 60%, or more by 2050 and do so sustainably on less resources – less land, less water, less fertilizer and less pesticides in an improved and more sustainable environment.
- Increased demand for crop biomass to produce biofuels in response to more energy required for a more demanding and affluent growing world population.
- Respond to the additional new challenges associated with climate change, with more frequent and severe droughts with implications for availability and use of water – agriculture uses 70% of the fresh water in the world, a rate that is not sustainable by 2050 with 2 billion more people.
- Globally, 870 million people are currently chronically hungry and 2 billion are malnourished. The world may consume more grain than it produced in 2014 whilst grain reserves are at a low level. It is imperative that insufficient and unaffordable food will lead to political instability and food riots such as in 2008 when price of food commodities peaked.
- Rates of growth in crop productivity have declined subsequent to the significant contribution of the green revolutions of wheat and rice. It is now evident that conventional crop technology alone will not allow us to feed over 9 billion in 2050 and neither is biotechnology a panacea. An option being proposed by the global scientific community is a balanced, safe and sustainable approach, using the best of conventional crop technology (well adapted germplasm) and the best of biotechnology (appropriate GM and /non-GM traits) to achieve **sustainable intensification**

of crop productivity on the 1.5 billion hectares of cropland globally. The returns on investments in agriculture are high and furthermore they directly impact on poverty alleviation, particularly small resource-poor farmers and the rural landless dependent on agriculture, representing the majority of the world's poorest people.

The commentaries that follow provide more information and amplification on some of the above issues as they relate to crop biotechnology and more specifically GM/biotech crops which can make a significant contribution to global food security.

- **UN Population Projections and Food Demand**

The United Nations (UN) released in June 2013, the new population projections based on data until 2012. The data reveals that, contrary to previous reports, the world population is unlikely to stop growing this century. There is an 80% probability that the world population, now 7.2 billion people, will continue to increase to between 9.6 billion and 10.9 billion in 2100. This uncertainty is much smaller than the range from the traditional UN high and low variants. Much of the increase is expected to happen in Africa, in part due to higher fertility rates and a recent slowdown in the pace of fertility decline. Also, the ratio of working-age people to older people is likely to decline substantially in all countries, even those that currently have young populations (UN DESA, 2012).

The increase in population growth will occur in high fertility countries mainly in Africa, India, Indonesia, Pakistan, the Philippines and the United States. The population of Africa could more than double by mid-century, from 1.1 billion today to 2.4 billion in 2050, and potentially reaching 4.2 billion by 2100. Five of the top ten most populous countries in 2100 will be from Africa and in decreasing order they are: Nigeria (914 million), Tanzania (276 million), Congo (262 million), Ethiopia (243 million) and Uganda (205 million). The highest increase in Africa is estimated to occur in Nigeria which will surpass the USA before 2050 and could be alongside China as the second most populous country in the world at close to 1 billion. This is a startling scenario as Africa has not been able to feed its current population of 1.1 billion.

Asian countries India, China, Indonesia, and Pakistan belong to the top 10 most populous countries in 2100. India which is projected to be the number 1 most populated country in 2050 at 1.6 billion will surpass China in year 2028 with populations of around 1.45 billion. Henceforth, it will decline slowly to 1.5 billion in 2100, similarly with China's population which will decline to 1.1 billion. By 2100, Indonesia's population will reach 315 million, Pakistan at 263 million, Philippines will be at 188 million and Bangladesh at 182 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 462 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 2014 edition of "Food Insecurity in the World" presents the updated estimates of undernourishment and progress towards the Millennium Development Goals and World Food Summit hunger targets. The Report indicates that global hunger reduction continues with about 805 million people to be chronically undernourished in 2012-2014, the prevalence of undernourishment has fallen from 18.7 to 11.3 percent globally and from 23.4 to 13.5 percent for developing countries. The figures demonstrate that the hunger target of the Millennium Development Goal – of halving the proportion of undernourished people in developing countries by 2015 – is within reach.

Marked differences across regions persist especially in Latin America and the Caribbean where the greatest overall progress in increasing food security occurred, and where they have strengthened their political commitment to food security and nutrition. Modest progress in sub-Saharan Africa and Western Asia were observed which have been afflicted by natural disasters and conflict with some minimal political commitments. It can be surmised that sustained political commitment at the highest level, with food security and nutrition should be the top priorities in order to eradicate hunger.

The Report concluded that Hunger reduction requires an integrated approach, and needs to include: public and private investments to raise agricultural productivity; better access to inputs, land, services, technologies and markets; measures to promote rural development; social protection for the most vulnerable, including strengthening their resilience to conflicts and natural disasters; and specific nutrition programmes, particularly to address micronutrient deficiencies in mothers and children under five (Food and Agriculture Organization, 2014).

In the next fifty years, the world will consume up to 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 181.5 million hectares equivalent to more than 10% of global arable land.

- **Small Resource-poor Farmers**

ISAAA's mission is to increase crop productivity through the application of new technologies with a particular focus on alleviating poverty of small resource-resource poor farmers, who represent the majority of the world's poorest people. Small farms have been defined by various criteria (Hazell et al, 2010; Nagayets, 2005; Lipton, 2005; and World Bank, 2003). The most common features used to define small farms are size of land holding and dependency on family labor. The definition of small farms used in the ISAAA Briefs is 2 hectares or less of crop land and/or with the majority of labor being provided by family members. The following commentary on small farms is mainly drawn from the above four key references.

There are approximately 525 million (half a billion) small farms globally which are becoming smaller and more numerous as they are inherited by larger number of family members. Small farmers and their families comprise about 2.5 billion people globally and the poorer amongst them represent about 70% of the poorest people in the world (~50% are poor farmers and 20% are the rural landless who are completely dependent on agriculture for their livelihoods). Today, poverty is largely a rural phenomenon closely linked to agriculture but this will change as urbanization progresses – more than 50% of the world population already lives in towns and cities. Based on a 525 million global total of small farms over three-quarters (87% or ~457 million) of the world's small farms are in Asia, 8% (~42 million) in Africa, only 4% (2 million) in Europe and the lowest number equivalent to 1% (0.5 million) in the Americas. Thus, the predominance (95%) of small farms are in the two continents of Asia and Africa where they account for >75% of the total crop hectarage. The top two countries with the largest number (in millions) of small farms (<2 hectares) in each of the four global regions are China with 189 million small farms (39% of global) and India with 92 million (18% of global) are by far the biggest; the two countries together account for over half (56%) of the global total of 525 million small farms.

Some of the important features of small farms, compared with large farms, are that they are more economically efficient, they generate more employment, and whilst increasing productivity on their own small farms, they also directly contribute to improvements in their own goals for food security and poverty alleviation. This is the case for the 7.1 million small farmers in China (an average of 0.5 ha of Bt cotton) and the 7.7 million small farmers in India (average of 1.5 ha of cotton) who are currently benefiting from Bt cotton, and the ~0.4 million farmers benefiting from biotech maize in the Philippines (average of 2 hectares of biotech maize).

Another important factor is that given that family labor is infinitely more motivated than hired labor, there is also more incentive for small farmers to adopt new technologies. As the green revolution in wheat and rice in Asia clearly demonstrated, small farmers are quick adopters of new technologies and thus the number of beneficiaries of new technologies can escalate quickly. For example, it is estimated that of the 18 million farmers who adopted biotech crops in 2014, more than 16.5 million equivalent to more than 90% were small resource poor-farmers. This trend for high adoption by small farmers will continue as countries like Bangladesh and Indonesia, (they tie for the third largest number of small farms per country in the world at 17 million each) and Vietnam will start to adopt biotech crops. Indonesia approved biotech sugarcane for commercialization in 2013 which is more of an estate crop on larger hectarages but is also expected to adopt biotech maize in the near term. Bangladesh is conducting field trials of biotech potatoes and, in October 2013 approved for commercialization, for the first time, a GM food staple Bt brinjal commercialized in 2014.

As was also demonstrated during the green revolution of wheat and rice, increased productivity on small farms can also be the engine of growth for the local rural communities because long distance high cost transport is not required to deliver locally produced food which is consumed in the same location where it was produced.

- **Food Security and Climate Change**

Catherine Bertini, the Chicago Council on Global Affairs co-chair has observed that ***"Growth in the agriculture sector is twice as effective at reducing poverty as growth in other sectors. A global food security strategy centered on agricultural development will alleviate poverty, guard the world's natural resource base, make agriculture more resilient to climate change and contribute to economic growth and social stability in low-income countries."***

The study reported that ***"although there has been progress in advancing global food security, investments in science need to be ramped up to increase production sustainably and nutritiously. Innovations especially need to be targeted to small scale farmers in developing countries, whose productivity must be increased if the world is to raise food production by at least 60 percent by 2050."***

Numerous studies in the past decade have predicted the effects of climate change on food security such as global yields, commodity price, and nutritional quality. In a Food Security Report published by the UK Environment, Food and Rural Affairs Committee, it was noted that UK's self sufficiency on food has declined over the years. Thus, the long-term challenge for the food production system is to produce more food despite the negative effects of climate change. The Report supports the idea of **sustainable intensification** which means producing more food with less resources on the current 1.5 billion hectares of crop land globally. The report calls on the Department for Environment, Food, and Rural Affairs (DEFRA) to stem decline in the UK self-sufficiency and deliver more resilience in the UK food system (Crop Biotech Update, 2 July 2014). Researchers David Lobell of Stanford University and Claudia Tebaldi from the National Center for Atmospheric Research found that there is substantial increased risk over the next two decades of a major slowdown in the growth of global crop yield. They opined that whereas the odds of a major production slowdown of wheat and maize are not high, the risk is about 20 times more significant than it would be without global warming (Crop Biotech Update, 30 July 2014). Similar results were obtained in a study by nine leading global research teams under the Agricultural Model Intercomparison and Improvement Project (AgMIP) and the Inter-Sectoral Impact Model Intercomparison Project (ISI-MIP). Analysis reveals that the average climate change effect on crop yields is a 17 percent decline, but with significant differences by crop, region, and climate models. The final average yield effect is an 11 percent decline as farmers respond by altering input use and management practices on increasing agricultural area, expanding production into new areas (an increase in area globally of about 8 percent) and reduced consumption (a decline of about 3 percent) (Crop Biotech Update, 30 July 2014). Food quality will also suffer with rising CO_2 due to climate change, as shown by a study on wheat by University of Californa, Davis plant scientist Arnold Bloom. Elevated levels of CO_2 inhibit plant's assimilation of nitrate into proteins indicating that the nutritional quality of food crops is at risk as climate change intensifies. Other studies have also indicated that protein concentrations in the grain of wheat, rice, barley as well as potato tubers will decline on average by approximately 8 percent under elevated levels of atmospheric dioxide (Crop Biotech Update, 10 April 2014).

Increased population, food insecurity and climate change may indeed impact food availability and accessibility for poor and hungry people. Various initiatives have been put in place in countries to at least reduce this impact, and whereas biotechnology can make an important contribution, it is not a panacea to solve all problems. A number of acceptable and feasible biotechnologies have been developed through the years that can in many ways meet these enormous challenges.

MEETING THE CHALLENGES

A new and comprehensive global meta-analysis of benefits from biotech crops

A 2014 comprehensive global meta-analysis of benefits from biotech crops of 147 published biotech crop studies over the last 20 years, confirmed the significant and multiple benefits that biotech crops have generated over the past 20 years (1995 to 2014). The meta- analysis was performed using primary data from farm surveys or field trials world-wide and reporting impacts of GM soybean, maize, or cotton on crop yields, pesticide use, and/or farmer profits. The authors of the meta-analysis concluded that ***"on average, GM technology adoption has reduced chemical pesticide use by 37%, increased crop yields by 22%, and increased farmer profits by 68%. Yield gains and pesticide reductions are larger for insect-resistant crops than for herbicide-tolerant crops. Yield and profit gains are higher in developing countries than in developed countries."*** The authors concluded that ***"this meta-analysis confirms that – in spite of impact heterogeneity – the average agronomic and economic benefits of GM crops are large and significant. Impacts vary especially by modified crop trait and geographic region. Yield gains and pesticide reductions are larger for IR crops than for HT crops. Yield and farmer profit gains are higher in developing countries than in developed countries. Recent impact studies used better data and methods than earlier studies, but these improvements in study design did not reduce the estimates of GM crop advantages. Rather, NGO reports and other publications without scientific peer review seem to bias the impact estimates downward. But even with such biased estimates included, mean effects remain sizeable"*** (Klumper and Qaim 2014).

The Contribution of Biotech Crops to Sustainability

Since 1996, 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. Provisional economic gains at the farm level of ~US$133.3 billion were generated globally by biotech crops during the eighteen year period 1996 to 2013, of which 30% were due to reduced production costs (less ploughing, fewer pesticide sprays and less labor) and 70% due to substantial yield gains of 441.4 million tons. The 441.4 million tons comprised 138.2 million tons of soybean, 273.5 million tons of maize, 21.7 million tons of cotton lint, and 8 million tons of canola over the seventeen year period 1996 to 2013. For 2013 alone, economic gains at the farm level were US$20.4 billion, of which approximately 12%, were due to reduced production costs (less ploughing, fewer pesticide sprays and less labor) and approximately 88%, due to substantial yield gains of 64 million tons. The 64 million tons comprised 15.9 million tons of soybean, 44.2 million tons of maize, 2.8 million tons of cotton lint, and 1.1 million tons of canola (Brookes and Barfoot, 2015, 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 441.4 million tons of additional food, feed and fiber produced by biotech crops during the period 1996 to 2013 had not been produced by biotech crops, an additional 132 million hectares of conventional crops would have been required to produce the same tonnage. Some of the additional 132 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 2013 alone, if the 64 million tons of additional food, feed and fiber produced by biotech crops during 2013 had not been produced by biotech crops, an additional 18 million hectares of conventional crops would have been required to produce the same tonnage for 2013 alone (Brookes and Barfoot, 2015, 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 ~16.5 million poor farmers in 2014, and this can be enhanced significantly in the remaining years of this decade 2010 – 2020.** 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 strategize about the contributions that biotech crops can make beyond the 2015 Millennium Development Goals.**

- **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 based on the latest information for the period 1996 to 2012 was estimated at 497 million kilograms (kgs) of active ingredient (a.i.), a saving of 8.7% in pesticides, which is equivalent to a 18.5% 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 2012 alone was a reduction of 36 million kgs a.i. (equivalent to a saving of 8% in pesticides) and a reduction of 23.6% in EIQ (Brookes and Barfoot, 2014).

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 9.6 billion by 2050. The first biotech maize hybrid with a degree of drought tolerance was commercialized in 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 such as sugarcane in Indonesia and wheat in Australia which has performed well in initial field trials, with the best lines yielding up to 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. Provisionally in 2013 alone, this was an estimated saving of 2.1 billion kg of CO_2, equivalent to reducing the number of cars on the roads by 0.93 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 2013 to 25.9 billion kg of CO_2, or removing 11.5 million cars off the road. Thus in 2013 alone, the combined permanent and additional savings through sequestration was equivalent to a saving of 28 billion kg of CO_2 or removing 12.4 million cars from the road up from 11.8 million in 2012 (Brookes and Barfoot, 2015, 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 — 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.

Stewardship and Resistance Management of Biotech Crops

The two major biotech crop traits of insect resistance (IR) and herbicide tolerance (HT) have made an enormous contribution to global food, feed and fiber production since they were first approved for commercial cultivation in 1996, almost 20 years ago. In 2014, insect resistance and herbicide tolerance traits, were deployed singly or stacked in the four principal biotech crops of maize, soybean, cotton and canola, and were planted globally on 181 million hectares in 28 countries (James, 2014; Marshall, 2014). Moreover, in the 19 year period, 1996 to 2014 the IR/HT biotech crops have gained the trust of millions of farmers world-wide and as a result have achieved a near-optimal adoption of 90% or more in virtually all the principal countries growing biotech crops. The IR/HT biotech crops have provided a successful complementary and alternative system to the conventional pesticide-based crop production systems and they are judged by farmers to be efficient, convenient and environmental-friendly. Notably, Scientific American included biotech-based insect resistance (IR) and herbicide tolerance (HT) traits in a list of 10 biotechnology innovations that have revolutionized agriculture (Scientific American, 2014). These same two trait(s) have also been successfully incorporated in a range of other commercialized biotech crops including alfalfa, brinjal (eggplant), sugar beet and poplar; the two traits have also been successfully incorporated in the other two major staples of rice and wheat for future deployment as new commercial biotech crops.

The insect resistance trait in biotech crops expresses insecticidal proteins that control targeted insect pests, whereas the herbicide tolerant trait confers tolerance to herbicides (mainly glyphosate and glufosinate) and controls weeds without damaging the crop. Irrespective of whether the technology is conventional or biotech, the wide-spread adoption of insect resistance and herbicide tolerance leads, over time, to insect pest resistance and resistant weeds, thereby diminishing their benefits to farmers. **The issues of resistance management of IR/HT traits were anticipated and discussed by the scientific community, regulators and policy makers prior to the introduction of biotech crops in 1996.** Accordingly, several scientific and policy approaches were considered to manage the development of resistance in IR/HT crops, prior to and during their deployment in 1996 (McGaughey and Whalon, 1992; Bates et al., 2005 and Dill et al., 2007). The policy approaches ranged from the deployment of refugia, integration of IRM into general insect pest management (IPM) schemes using insect resistant management (IRM) strategies, and post release monitoring of biotech crops for early detection of resistance. Coincidentally, new scientific methods evolved around gene pyramiding, and stacking of traits to enable more effective management and stewardship of resistance in the new biotech crops. Thus, resistance management including IRM, stewardship, and good farming practices, including have played a significant role in the successful large scale adoption and acceptance of IR/HT biotech crops from the very beginning in 1996. These approaches are credited with prolonging the life of biotech crops, and making them more durable than conventional technology thereby extending the benefits to farmers from planting IR/HT biotech crops season-after-season.

As anticipated, studies have confirmed that the first generation IR and HT traits are becoming susceptible to resistant targeted insect pests and weeds respectively. Single or stacked IR/HT GM crops involving single and multiple gene(s) in maize in the USA have led to field-evolved resistance of insect pests. Hence, approaches for managing Bt resistance must be assigned a high priority, particularly as more crops feature Bt genes (single and stacked) and in 2014 already occupied over 55 million hectares. It is noteworthy that the first stacked IR/HT soybean was launched in 2013 in four countries in Latin America, and Bt brinjal was also introduced in Bangladesh in 2014. A study by Gassman et al. (2014) documents the field-evolved resistance by western corn rootworm to multiple Bacillus thuringiensis toxins in biotech maize crops. It also confirms that IR GM crops producing less than a high dose of toxin against target pests may select for resistance rapidly. Similarly, several studies indicate that a considerable number of weeds have shown resistance to the application of herbicides including the widely used glyphosate, thereby potentially limiting the future use of the product in its current form. Thus, the management of insect resistance and stewardship of IR/HT biotech crops have assumed greater importance, and deserves priority and appropriate attention and implementation at the field level.

The current system of policy and scientific approaches to effectively manage IR/HT crops has served its purpose for 20 years. A paradigm shift in technology to new more resilient and durable technologies and stewardship along with strict implementation of the current policy and scientific approaches are judged by observers to be of the highest priority in order to sustain future gains from IR/HT biotech crops. The two decades of experience and the trend in technological development suggest that the following 12 elements be considered to achieve effective and strict implementation of resistance management and stewardship:

- Planting of refugia and innovative methods for deploying them in such simple but creative schemes such as refuge in the bag (RIB)
- Integration of IRM in integrated pest management (IPM) systems
- Stricter implementation of package of recommended practices
- Post release monitoring and timely reporting of detection of resistance
- Ensuring seed purity and adequate expression of traits
- Assurance of supply of high quality IR/HT seeds
- Gene pyramiding and stacking of insect resistance and herbicide tolerance traits
- Integrating multiple modes-of-action for IR/HT traits
- Development of innovative and more resilient new technologies capable of reversing resistance
- Timely replacement of current IR/HT products with improved versions
- Education, training and outreach to the farming community in managing IR/HT biotech crops and,
- Strengthen compliance of regulatory requirements

Early as possible approvals of the second generation of IR/HT crops such as Bollgard-III™ and Enlist™ products (USDA, 2014) with dual and triple modes-of-action for insect and weed tolerant traits is important, and helps overcome the current challenges of managing the insect and weed resistance to IR/HT crops. The wide scale use of the refuge-in-bag (RIB) strategy and regulatory compliance needs to be strictly implemented. In addition, farmers, the scientific community and industry have to work in tandem to devise on-farm and off-farm strategies to prolong durability of resistance. The need for appropriate and strict management of resistance and stewardship is greater in developing countries (than industrial countries) where the constraints are much greater. Farmers in developing countries in particular need to be more aware and educated about the importance of good quality seeds, planting of refugia, and compliance with the recommended agronomy and crop management practices; this includes safe and appropriate use of pesticides based on objective assessments of economic threshold levels (ETLs). Developing countries in particular, also need to consider the timely replacement of existing products with improved products, to enhance the value and durability of IR/HT technology. Farmers must also be made more aware of the importance of scouting for surviving larvae of pests and the need to apply timely pesticides to eradicate resistant larvae. Farmers must exercise diligence in planting of refugia as this will help in prolonging the life of IR/HT technology and extending the benefits to farmers in planting biotech crop season after season. Education and increased awareness of the importance of managing resistance is paramount as well as strict implementation of recommended practices. **Importantly, all stakeholders including the scientific community, farmers, policy makers and the private sector must be made aware of their collective responsibility and the fact that the overall system of managing resistance will NOT work if any single stakeholder is delinquent in its implementation.**

Increased adoption of biotech drought tolerant maize in the US

The estimated hectares of DroughtGard™ maize with event MON 87460 planted in the US in 2013 was 50,000 hectares and in 2014 was of the order of 275,000 hectares. This is equivalent to a large 5.5 fold year-to-year increase in planted hectares between 2013 and 2014, and reflects strong US farmer acceptance of the first biotech-derived drought-tolerant maize technology to be deployed globally. It is noteworthy that Event MON 87460 was donated by Monsanto to the Water Efficient Maize for Africa (WEMA) a public-private partnership (PPP) designed to deliver the first biotech drought tolerant maize to selected African countries starting 2017.

A selection of "new" biotech crops approved and planned for commercialization in 2015 and beyond; they include two new food staples, potato and the vegetable brinjal (eggplant)

In 2014, the US approved the following two new biotech crops for cultivation starting in 2015; Innate™ potato, a food staple with lower levels of acrylamide, a potential carcinogen, and less wastage due to bruising; reduced lignin alfalfa event KK179, to be marketed as HarvXtra™ with higher digestibility and higher yield. Another product Enlist™ Duo is a representative example of the second generation of HT products featuring dual-action/weed management systems for dealing with herbicide resistant weeds. Others in the same class include a dicamba/glyphosate soybean product, and event SYHTOH2 soybean tolerant to glufosinate, isoxaflutole and mesotrione. Enlist™ Duo has herbicide tolerance to both glyphosate and 2,4-D in soybean and maize. Indonesia has approved drought tolerant sugarcane with plans to plant in 2016 and Brazil has two products – Cultivance™, an HT soybean, and a home-grown virus resistant bean for commercialization in 2016. Finally, Vietnam has approved biotech maize (HT and IR) for the first time with commercialization planned for 2015. In summary, in addition to the current biotech food crops which directly benefit consumers (white maize in South Africa, sweet corn and sugar beet in the US and Canada, and papaya and squash in the US) new biotech food crops include the queen of the vegetables (brinjal) in Bangladesh and potato (the fourth most important food staple in the world) in the US.

- **Innate™ potato** developed by the private company, Simplot, in the US, was approved for commercialization in the US by APHIS/USDA in November 2014. Innate™ has 50 to 75% lower levels of acrylamide, a potential carcinogen in humans, produced when potatoes are exposed to high temperatures. Innate™ potato is also less susceptible to bruising. Given that potato is a perishable food product, quality can be significantly and negatively impacted by damage to the tubers during harvest, handling and processing. Innate™ potatoes are an excellent example of how biotech crops can enhance food safety, quality and provide benefits for all stakeholders, growers, processors and consumers. It is noteworthy that Innate™ potato was developed by transferring genes from one potato variety to another. Simplot claims that Innate™ potato is a safe and superior product that will confer the following benefits to farmers, processors and consumers: lower levels of asparagine, which in turn lowers the potential for production of undesirable acrylamide, a potential carcinogen, when potatoes are exposed to high temperatures; will not discolor when peeled; fewer spots due to bruising; they store better; reduce wastage and thus contribute to food security. Consumer surveys by Simplot indicate that 91% of those surveyed were comfortable with the Innate™ breeding method. RNA interference technology was used to silence four genes that lowered enzyme levels that in turn led to lower acrylamide level. The company plans to initiate commercialization on a modest hectarage in 2015, prioritizing the fresh potato market and the potato chip market whilst keeping Innate™ production separated from conventional potatoes for the export market. Simplot is planning on submitting applications to the major markets, Canada, Mexico and Japan.

Approval of Innate™ could open new windows of opportunity for biotech potatoes globally. Potato is the fourth most important food staple in the world after rice, wheat, and maize. Plant protection constraints are important in potato production because the potato is a vegetatively propagated crop, where the tubers and not the "true seed" are used to propagate the crop commercially. Thus, unlike crops propagated through the seed, potatoes do not benefit from the natural barrier provided by the seed for blocking transmission of many plant pathogens. Hence, like other tuber crops, the prevalence and importance of diseases is high in potatoes, compared with seed propagated crops. Global yield loss in potatoes due to fungal and bacterial pathogens is estimated at 22%, plus 8% for viruses for a total of 30% for all diseases. These disease losses are in addition to the estimated losses of 18% for insect pests and 23% for weeds. Without crop protection, up to 70% of attainable potato production could potentially be lost to pests such as Colorado beetle and virus vectors (aphids and leafhoppers), diseases caused by fungi, bacteria and a complex of viruses, including potato virus Y (PVY) and potato leaf roll virus (PLRV) as well as nematodes, which cause devastating losses in localized areas. Seed certification programs, for field tubers grown for propagation, and plant tissue cultural systems, both requiring infrastructure and recurrent use of resources to produce clean potato stock annually, are used in industrial countries to provide effective control of some diseases particularly insect vectored viruses including PVY and PLRV. Certification is not very effective against the spread of destructive late blight and certification requires adequate infrastructure which is often not available in developing countries. Thus, potato suffers very high losses from pests and diseases, which biotech can effectively control.

Of the many pests that attack potatoes, late-blight (caused by the fungus *Phytophthora infestans*) is the single most important disease, accounting for up to 15% of potato yield losses due to plant pathogens – the disease that has caused the Irish Famine of 1845. More than 150 years after the famine, conventional technology has still failed to confer resistance and late-blight is still the most important disease of potatoes world wide responsible for economic losses estimated at US$7.5 billion annually.

Potato is widely grown in many developing countries like Bangladesh, India, and Indonesia where field trials are already underway for assessing biotech resistance to late-blight disease of potatoes. The approval of Innate™ potato in the US could have important implications globally particularly for developing countries, because it opens up new opportunities to apply biotech to a "new" crop by stacking several important traits already developed (late-blight resistance), approved (Innate™), or already commercialized (PVY, PLRV and Bt in the US in the late 1990s). It is noteworthy that recently, Simplot has pioneered this strategy by licensing biotech late blight resistant potato from the John Innes Institute in the UK and developed the late blight resistant potato with low acrylamide potential, reduced black spot bruising and lowered reducing sugars. The company has submitted an application for non regulated status to APHIS, and through an enhanced petition review process, APHIS has already invited public comments on the application.

- **Reduced lignin alfalfa event KK179** (to be marketed as HarvXtra™) was recently deregulated by APHIS for cultivation in the US. Alfalfa is a perennial and the fourth largest crop by hectarage in the US after maize, soybean and wheat, occupying up to 8 to 9 million hectares. It is the major forage crop in the US and globally, where it occupies approximately 30 million hectares. Biotech herbicide tolerant RR® alfalfa has already been grown since 2005 in the US. In November 2014, the US approved the planting of biotech alfalfa, event KK179, to be marketed as HarvXtra™, a stack with RR® alfalfa with up to 22% reduction in lignin when compared to conventional alfalfa at the same stage of growth. This results in a reduced overall accumulation of total lignin in alfalfa forage. The amounts of lignin in event KK179 forage are generally similar to those found in conventional forage harvested several days earlier under similar production conditions. The reduced lignin alfalfa increases forage quality compared to conventional forage of the same age, maximizes forage yield by delaying harvest for several days, and gives farmers more flexibility in forage harvest timing. Thus, event KK179 maximizes forage quality with lower lignin levels; optimize forage yields by allowing farmers to delay harvest for several days during which more forage biomass is accumulated; and allow more flexible harvest schedules to cater for adverse weather and labor schedules.

- **Enlist™ Duo** is a representative example of the second generation herbicide tolerant products featuring dual-action/weed management systems for dealing with herbicide resistant weeds – others in the same class includes a dicamba/glyphosate soybean product and event SYHTOH2 soybean tolerant to glufosinate, isoxaflutole and mesotrione. **Enlist™ Duo** products contain two pyramided genes to confer tolerance to herbicide glyphosate and 2,4-D choline. The product was deregulated in the US to manage broad spectrum of weeds including hard-to-control and resistant weeds such as glyphosate-resistant Palmer amaranth, waterhemp and giant ragweed. Maize and soybean farmers may include the Enlist™Duo seeds in their stewardship of rotating various herbicide tolerant seeds and products in their farms – an important strategy to keep the value and effectiveness of herbicide tolerant crops. A full launch of Enlist products is pending import approval in China which approved the last product in June 2013; asynchronous approval for cultivating and import is a major challenge which needs urgent attention by all stakeholders.

Highlights of Biotech Crops in Developing Countries in 2014

- **Achievement in Bangladesh**

A small, poor country Bangladesh has successfully overcome various interventions and made a historical decision in 2014 to plant its first biotech crop, Bt brinjal. This action is evidence that political will and support from a public sector through a public-private partnership can allow the public sector to work together with a private sector company from India towards common goals that benefit the poor people of Bangladesh. The decision to approve the product was made on 30 October 2013 and in record time – less than 100 days – planting commenced on 22 January 2014. The four Bt varieties approved were:

- BARI Bt brinjal-1 or Uttara was approved for planting in Rajshahi region
- BARI Bt brinjal-2/Kajla in Barisal region
- BARI Bt brinjal-3/Nayantara in Rangpur and Dhaka regions, and
- BARI Bt brinjal-4/Iswardi or ISD006 in Pabna and Chittagong regions.

Brinjal/eggplant is an important food staple in Bangladesh as well as in other countries in South Asia. The adoption of Bt brinjal in Bangladesh is a unique demonstration of strong political will from Government particularly the Honorable Minister of Agriculture Matia Chowdhury, who personally distributed the first Bt brinjal seedlings for commercial planting on 22 January 2014. Through a successful crop biotech tripartite arrangement between a public R&D institute (BARI), private seed company (Mahyco) and regulatory agency in Bangladesh under a USAID led program – the Agricultural Biotechnology Support Project II (ABSP-II), Bt brinjal project was developed. Mahyco generously donated the Bt Elite Event (EE-1) to BARI in 2005. The limited commercial cultivation of Bt brinjal by 120 farmers in 2014 demonstrated the substantial reduction in insecticide sprays resulting in a significant saving in cost of production, and a bonus of blemish free brinjal fruits with excellent marketability. Bt brinjal increases marketable yield by at least 30% and reduces the number of insecticide applications by 70-90%, resulting in a net economic benefit of up to US$1,868 per hectare. It is estimated that at the national level, Bt brinjal has the capacity to generate a net additional economic benefit of US$200 million per year for around 150,000 brinjal growers in Bangladesh.

- **Progress in Vietnam**

Due to low domestic maize production of variable quality, Vietnam had to more than quadruple its maize imports for animal feed. During the last four years, imports have increased from ~1 million tons in 2011 to an estimated 4.5 million tons in 2014. Vietnam spent around US$600 million importing 2.33 million tonnes of maize in the first half of 2014. It is projected that total maize imports for 2014 will cost more than US$1 billion. In order to decrease dependency on costly imports, in September 2014, the Ministry of Agriculture and Rural Development (MARD) granted licences for the following four biotech maize hybrids:

- MON 89034, pyramided insect resistant (Dekalb Vietnam Co., Ltd.)
- NK603, herbicide tolerant (Dekalb Vietnam Co., Ltd.)
- Bt11, insect resistant (Syngenta)
- MIR162, insect resistant (Syngenta)

The import approvals of the four hybrids came following careful evaluation of dossiers submitted to the Council of Food Safety for GM Food and Animal Feed for consideration, which confirmed that the products had no harmful effects on health. Three GM maize events were granted biosafety certificates in 2014 by the Ministry of Natural Resources and Environment (MoNRE):

- MON 89034, pyramided insect resistant (Dekalb Vietnam Co., Ltd.)
- GA21, herbicide tolerant (Syngenta)
- NK603, herbicide tolerant (Dekalb Vietnam Co., Ltd.)

These series of approvals may lead to the eventual planting of GM crops in the coming year and an affirmative step towards the government policy to advance agricultural technology.

- **Progress in Indonesia**

Indonesia is currently the fourth most populous country (252 million) in the world after China, India and the US: the population is projected to reach 366 million by 2050. The country meets its food requirements from 24 million hectares of arable land equivalent to 13% of the total 191 million hectares of land comprising thousands of islands. Indonesia is world's 12th largest sugarcane and sugar producing country with estimated planting of sugarcane of ~450,000 hectares in 2013-14, with a production of over 28 million tons per year. Latest projections for 2014 indicate that Indonesia will import 3.78 million tons of raw sugarcane and sugar which is an increase of 29% from the 2.8 million tonnes imported in 2013 (Rusmana and Listiyorini, 2014).

In order to decrease dependency on costly imported sugar, Indonesia has pursued the use of biotech drought- tolerant sugarcane to increase domestic production of sugar, through a public-private partnership (PPP) to facilitate technology transfer. In May 2013, Indonesia's Biosafety Commission for Genetically Modified Products (KKH PRG) announced the approval for commercialization of Indonesia's first home-grown biotech, genetically modified (GM) sugarcane, tolerant to drought. The product was approved for food biosafety, and approval for feed is pending. Approximately 50 hectares of biotech drought tolerant seed sets were planted in 2014 in anticipation of larger scale commercialization in 2015 pending feed approval.

- **Status of Golden Rice**

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.** Studies showed that vitamin A supplementation could reduce all mortality in children younger than 5 years by 24-30%. Vitamin A availability could prevent 1.3-2.5 million of the nearly 8 million late infancy and pre-school age child deaths in highest risk developing countries annually. Golden Rice (GR) is being developed by the Philippine Rice Research Institute (PhilRice) and the International Rice Research Institute (IRRI). IRRI reports that as of March 2014, the research, analysis and testing of beta carotene-enriched Golden Rice continues, in partnership with collaborating national research agencies in the Philippines, Indonesia, and Bangladesh. The Golden Rice event R (GR2-R) was introgressed into selected mega varieties, field tested for three seasons to evaluate the agronomic and product performance under Philippine field conditions (IRRI, 22 March 2014).

Preliminary results of the conducted multi locational trials shows that while the target level of beta-carotene in the grain was attained, yield was on an average lower than yields from comparable local varieties already preferred by farmers. Hence, the new objective of increasing yield became the focus of the current research to include other versions of GR2 such as GR2-E and others. At IRRI, the Golden Rice trait is being bred into mega varieties to get suitable advance lines, and once attained the series of confined field trials will resume. IRRI and its many research partners remain committed to developing a high-performing Golden Rice variety that benefits farmers and consumers. The important mission of the Golden Rice project – to contribute to improving the health of millions of people suffering from micronutrient deficiency – demands that every step and aspect of the scientific study of Golden Rice be carefully planned. IRRI and all participating organizations will continue to rigorously follow all biosafety and other regulatory protocols in continuing the research to develop and disseminate Golden Rice.

Once released, Golden Rice has the potential to provide beta carotene fortified carbohydrate staple, totaling an estimated of 2,006,869 calories per day in the major countries of the South suffering from VAD. The following is an approximate breakdown, by region per day: people living in South Asia (with 1,130,648 calories), Southeast Asia (660,979), Africa (125,124), Latin America (75,238), and Central Asia (14,880) for a total of 2,006,869 calories per day– these are the regions where most VAD occurs (HarvestPlus, Personal Communications).

Potential New Biotech Crops in the Next 5 to 10 Years

One of the concerns often voiced by critics of biotech crops is the narrow focus on four principal crops (soybean, maize, cotton, and canola) and two traits, (herbicide tolerance and insect resistance). However, in the last five years there have been a significant broadening of the number of commercialized biotech crops to include a significant hectarage of sugar beet, and alfalfa along with continued small hectarages of squash, papaya, sweet pepper, tomato, eggplant and poplar **for a total of 12 commercial biotech crops in 2014**. Subject to approval by APHIS/USDA in the US, Innate™ potato may be added to the list of commercialized biotech crops in the near term. Potato is particularly important because it is the fourth most important food staple in the world after rice, wheat and maize. Global Information on biotech crops undergoing field trials is of interest to many but it is not always easy to access the information. Appendix 7 provides an incomplete listing of selected "new" biotech crop/trait(s) that have, at a minimum, been field trialled at the equivalent of contained field trials (CFTs) level and therefore could potentially be candidates for approval in the next 5 to 10 years. The list is published in an attempt to provide the reader with a general global overview of the possible future scope of new biotech crops that may come available (subject to approval) during the next 5 to 10 years – detailed information on individual entries are not provided. The data base simply lists biotech crops by crop, trait(s), technology developer/facilitator, and country/ies where field tests have been conducted. Whereas the list of 71 entries is not exhaustive, in reviewing the data base of 71 entries, the following are some of the general salient features:

- **Overview, by country** – About half of the 71 entries are being field tested in developing countries and the balance are in industrial countries – the general shift in favour of developing countries is timely and appropriate given that the need for food, feed and fiber is most acute in the countries of the South, in Africa, Asia and Latin America where food security is a life threatening issue for millions of poor people and an urgent priority.

- **Overview, by crop** – About one-quarter of the 71 field trials are "new" biotech crops that substantially add to, and diversify, the current portfolio of 10 commercial biotech crops; even more important they are, by and large, pro-poor orphan crops that can make an important contribution to food security for poor people; listed alphabetically, they include apple, banana, camellina, cassava, citrus, chickpea, cowpea, groundnut, mustard, pigeon pea, potato, rice, safflower, sorghum, sugarcane, tomato and wheat.

- **Overview, by trait** – Whereas insect resistance (IR) and herbicide tolerance (HT) continue to be the major traits a much broader range of traits include the following new traits. Quality traits ranging from vitamin-A improvements in Golden Rice and bananas, enriched omega-3, anti-browning in potatoes and apple, high phytase and high oleic acid in maize to improved grain and flour quality in wheat are featured. New disease resistant (DR) crops range from bacterial wilt in bananas to virus diseases in cassava, potatoes and wheat (wheat virus mosaic in China) and greening disease in citrus in the USA; also featured prominently is late blight of potato, the most important disease of potatoes worldwide and soybean rust. Contamination of crops by mycotoxins and aflatoxins (for example, the fungal disease caused by *Fusarium*) is likely to become much more important, as food quality becomes a higher priority. Drought is an increasingly important trait and research is underway in several crops including maize, soybean, sugarcane and wheat. Nematode resistance in potatoes and soybean are in progress. Agronomic performance (AP) and yield/productivity are increasingly prevalent traits and trials are underway on low gossypol cotton, low lignin in alfalfa, and exploitation of heterosis in mustard. Yield enhancement is a primary long term goal and work is ongoing in several crops including soybean, maize and wheat. Nitrogen utilization (an annual US$50 billion expenditure on 100 million tons of N) is of interest to both industrial and developing countries and work is underway in Africa on rice with a parallel project on salinity. In summary, much progress has been made in the last five years to broaden a portfolio of crop/trait combinations that can better serve the need of developing countries. Experience to-date suggests that these technologies can be effectively transferred through public-private partnerships (PPP) which provides an effective mechanism for harnessing the comparative advantage of both public and private sectors to achieve the common goal of delivering improved biotech crops to small resource-poor farmers in developing countries.

- **Overview by technology developer** – Encouragingly about half of the listed entries represent technologies developed by public sector organizations or are technology transfer projects involving public-private sector partnerships. This, combined with the fact that about half of the trials are being conducted in developing countries, with an increasing number in Africa which presents the greatest challenges, is welcome news for the development community globally. To-date, the experience of the WEMA project has been very encouraging. The planned delivery of an insect resistant and drought tolerant stacked hybrid maize in Africa (likely to be in South Africa) in 2017 would be a land mark event and clearly demonstrate that public-private partnerships have a great deal to offer.

Non-transgenic Biotech Products

Up until now transgenic modification has been achieved using Agrobacterium or the gene gun. New advanced biotech applications such as **zinc finger nucleases (ZFN) technology, clustered regularly interspaced short palindromic repeat (CRISPR)–associated nuclease systems and transcription activator-like effector nucleases (TALENs)**, are being used to increase the efficiency and precision of the transformation process. These new techniques allow the cutting of the DNA at a pre-determined location and the precise insertion of the mutation, or single nucleotide changes at an optimal location in the genome for maximum expression. These techniques are well advanced – ZFN has already been used to successfully introduce herbicide tolerance and TALENs has been used to delete or "snip out" the gene in rice that confers susceptibility to the important bacterial blight disease of rice. **However, experts in the field believe that potentially the "real power" of these new technologies is their ability to "edit" and modify multiple native plant genes (non GM), coding for important traits such as drought and, generating useful improved crops that are not transgenic.** Regulators in the US have initially opined that changes not involving transgenic genes will be treated differently; this could have a very significant impact on the efficiency and timing of the current resource-intensive regulation/approval process and the acceptance of the products by the public.

Powdery mildew-resistant wheat was developed by researchers from the Chinese Academy of Sciences through advanced gene editing methods. Researchers deleted genes encoding for proteins that repress defenses against the mildew using TALENs and CRISPR genome editing tools. Wheat is a hexaploid and thus required deletion of multiple copies of the genes. This also represents a significant achievement in modifying food crops without inserting foreign genes, and hence considered t as a non-GM technique (Wang et al. 2014).

Another class of new applications, still at the early stages of development are **plant membrane transporters** that are being researched to overcome a range of crop constraints from abiotic and biotic stresses to enhancement of micronutrients. It is noteworthy that of the current 7 billion global population almost one billion is undernourished but another one billion is malnourished, **lacking critical micro nutrients, including iron (anemia), zinc and vitamin A.** Adequate supply of nutritious foods with enhanced levels of important micronutrients is critical for human health. Recent advances show that specialized plant membrane transporters can be used to enhance yields of staple crops, increase micronutrient content and increase resistance to key stresses, including salinity, pathogens and aluminum toxicity, which in turn could expand available arable land. Acid soils are estimated to occupy 30% of land globally.

Overview of Biotech Crops in Africa, Latin America and Asia

- **Africa**

Three countries in Africa, South Africa Burkina Faso and Sudan grew 3.2 million hectares of biotech crops in 2014 equivalent to 2% of the global 181.5 million hectares of commercialized biotech crops. In addition, a total of seven countries conducted field trials with biotech crops in 2014. These countries, listed alphabetically are: Cameroon, Egypt, Ghana, Kenya, Malawi, Nigeria, and Uganda. The key crops at various stages of experimentation in both confined and open trials include banana, cassava, cotton, cowpea, maize, rice, sorghum, sweet potato and wheat. The on-going trials focus 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. The expanding number of field trials is a consequence of achieving promising results in 2013 and an indication that Africa is progressively moving towards adopting important food security biotech crops. The research and field trial studies were all conducted under the aegis of existing legislation or stand-alone biosafety structures.

- **Latin America**

A total of 10 countries commercialized biotech crops in Latin America –they are, listed in order of hectarage, Brazil, Argentina, Paraguay, Uruguay, Bolivia, Mexico, Colombia, Chile, Honduras and Cuba. The total hectarage was 73.3 million equivalent to 40% of the global 181.5 million hectares commercialized globally in 2014. The key biotech crops in decreasing order of hectarage were soybean, maize and cotton. In 2014, Latin American countries planted a total of 5.8 million hectares of the stacked soybean, (Intacta™, launched in 2013) featuring both herbicide tolerance and insect resistance. Latin American countries led by Brazil as an emerging world leader, have benefitted significantly from biotech crops with Brazil alone provisionally estimated to have benefitted ~US$11.8 in the period 1996 to 2013 and US$3.4 million for 2013 alone (Brookes and Barfoot, 2015, Forthcoming).

- **Asia**

A total of seven countries commercialized biotech crops in Asia in 2014 – they are, listed in order of hectarage, India, China, Pakistan, Philippines, Australia, Myanmar and Bangladesh. The total hectarage was 20 million, equivalent to 11% of the global 181 million hectares commercialized globally in 2014. The key biotech crops in decreasing order of hectarage were cotton, maize, canola and brinjal. In 2014, Bangladesh grew a biotech crop for the first time – Bt brinjal (eggplant) on a total of 12 hectares. Of the three continents, Asia has the greatest potential for growth. Vietnam is expected to grow biotech crops for the first time in 2015 and Indonesia is also likely to grow a biotech drought tolerant sugarcane for the first time in 2015. Commercialization of biotech rice represents by far the biggest opportunity for Asia which grows and consumes 90% of the world's rice. The two most populous countries in the world China and India, with significant crop hectarages are potentially emerging world leaders in biotech crops. India has benefited significantly from biotech crops estimated at ~US$16.7 million in the period 1996 to 2013 and US$2.1 million for 2013 alone. China has benefited significantly from biotech crops estimated at US$16.2 million in the period 1996 to 2013 (Brookes and Barfoot, 2015, Forthcoming).

CLOSING COMMENTS

The Way Forward – The Role of Public-Private Partnerships (PPP)

In reviewing crop biotech transfer projects over the last decade the progress and promise of public-private sector partnerships (PPP) is striking. The first PPP biotech crop transfer project was facilitated by ISAAA in the early 1990s. The tripartite project involved three partners: the developing country partner was Mexico (more specifically the biotech lab CINVESTAV) which in conjunction with the Ministry of Agriculture had identified resistance to virus diseases in potatoes grown by small farmers as a top priority because conventional technology did not offer a solution; the private sector partner was Monsanto which agreed to donate the coat protein events that confer virus resistance to PVX and PVY in potatoes for use by small farmers in Mexico. Importantly, Monsanto also agreed to train scientists from CINVESTAV in the use of the new technology. The third partner was the Rockefeller Foundation which provided the entire funding for the 3 year project, because of its innovative nature and was consistent with the Foundation's program in crop biotechnology.

Following the implementation of the Mexican project, ISAAA further explored the possibility of building a biotech transfer project in which more than one country would share the same donated technology, thus providing a multiplier effect for technology transfer. The project that evolved featured the donation of an event for conferring resistance to the lethal papaya ringspot virus (PRSV) of papayas. The developing county partners were five countries in South East Asia, all of whom had identified PRSV as a common need and top priority because conventional technology did not offer a solution. The five developing country partners in South East Asia (where lead public sector laboratories in crop biotechnology were involved) were Indonesia, Malaysia, Philippines, Thailand and Vietnam. The private sector partner was Monsanto which agreed to donate the gene/s for virus resistance to PRSV in papaya for use by small farmers in the five respective partner countries. As in the Mexican project, Monsanto also agreed to train scientists from the five countries in South East Asia in the use of the new technology; the funding was provided by different donor agencies for a three year period. Subsequent to the establishment of the PRSV project, ISAAA facilitated a network of the five countries to share experiences and expedite progress with the technology. The network also provided an appropriate cost-effective mechanism for exchange of information and reciprocal training of project scientists among the five labs. Following interaction of the countries in the network, the five countries collectively identified a second papaya trait deemed important by all parties – delayed ripening. It is an important trait for a perishable fruit such as papaya which suffers significant post harvest losses – the technology for delayed ripening was donated by Zeneca.

In the last decade or so, many aid agencies and foundations have established projects to facilitate donation and transfer of crop biotech applications from both the private and public sector for the benefit of developing countries, particularly for small resource-poor farmers. Examples include, AATF based in Nairobi serving the needs of African countries, and Agricultural Biotechnology Support Project (ABSPII) which is a United States Agency for International Development (USAID bilateral program, with global activities and operated by Cornell University.

A preliminary review of the initiatives involved in biotech crop transfer projects from both the public and private sector, suggests that the PPP projects have been relatively successful and offer advantages that increases the probability of delivering an approved biotech crop product at the farmer level, within a reasonable time frame. Four PPP case studies have been selected to review and illustrate the diversity in characteristics of the four model projects: Bt brinjal in Bangladesh, herbicide tolerant soybean in Brazil, drought tolerant sugarcane in Indonesia, and the WEMA project for drought tolerance in maize in selected countries in Africa. For the convenience of readers, short description of each of the four case studies with more specific details are summarized in four boxes at the end of this closing chapter.

It is noteworthy that geographically, the selected four PPP case studies cover activities in all three continents of the South – Africa, Asia and Latin America. The four models also span developing countries which are at very different stages of development, ranging from small poor countries like Bangladesh and African countries (WEMA) to lead emerging countries like Brazil. The four model projects also cover a broad range of crops from major staples – maize in the Africa WEMA project, to soybean in Brazil, drought tolerant sugarcane in Indonesia, to pro-poor small farmer vegetable crops like Bt brinjal in Bangladesh. Similarly a broad range of traits is embraced by the four projects from drought tolerant maize in Africa and drought tolerant sugarcane in Indonesia, to herbicide tolerance in Brazil and insect resistance in Bangladesh. Finally the institutions that are providing financial support range from philanthropic Foundations (Bill and Melinda Gates and Howard Buffet in the WEMA project), to bilateral agencies (USAID and ABSPII) for Bt brinjal in Bangladesh and Brazilian government support through EMBRAPA funding the soybean project in Brazil. Donors of technology range from multinationals like Monsanto to private sector companies like Mahyco from developing countries.

In terms of delivering product, which is the principal objective of biotech transfer projects, the performance in all four case studies is encouraging. In Bangladesh the product Bt brinjal has already been approved and commercialized. In Brazil the product herbicide tolerant soybean has been approved with commercialization in 2016 pending approval for import into the EU. The product in Indonesia, drought tolerant sugarcane, has been approved for food with 50 hectares of seed setts planted ready for commercialization in 2015, pending approval for feed. The product for selected African countries, drought tolerant maize is progressing well with a projected delivery of the first product in South Africa in 2017, as planned, and followed by Kenya, Uganda and Mozambique and Tanzania.

Collectively, progress in the timely delivery of a product in the four PPP case studies is very encouraging. A more comprehensive analysis of the four projects would be useful to determine more definitively the secrets of success, with a view to building new and even more effective PPP projects in the future. **PPP projects are effective in that they harness the comparative advantages of all the respective stakeholders and embrace the philosophy of working equitably together towards common goals – North working with the South; Public sector working with the Private sector, using both conventional and biotechnology. Public-Private Partnerships are symbiotic and can generate substantial benefits by canalizing the collective efforts of very different partners towards equitable achievement of the common goals of food security and the alleviation of poverty and hunger and to feed a global population of 9.6 billion in 2050 and close to 11 billion in 2100 at the turn of the century.**

Norman Borlaug's Legacy and Advocacy of Biotech Crops

It is fitting to close this ISAAA Brief for 2014 by chronicling the counsel of the late 1970 Nobel Peace Laureate, Norman Borlaug, on biotech/GM crops, whose birth centenary was honored on 25 March 2014. Norman Borlaug, who saved a billion people from hunger, was awarded the Nobel Peace Prize for the impact of his semi-dwarf wheat technology on the alleviation of hunger. Borlaug was the founding patron of ISAAA, and also the greatest advocate for biotechnology and biotech/GM crops, because he knew their critical and paramount importance in feeding the world of tomorrow.

The following are powerful two memorable and historical self-explanatory quotes from the man who knew more than anyone about feeding the world of tomorrow, because he had achieved it in the green revolution and understood the profundity of the proverb – **reading is learning, seeing is believing, but doing is knowing – knowledge**. This Brief seeks to share knowledge about biotech crops whilst respecting the rights of readers to make their own decisions about biotech/GM crops.

"Over the past decade, we have been witnessing the success of plant biotechnology. This technology is helping farmers throughout the world produce higher yield, while reducing pesticide use and soil erosion. The benefits and safety of biotechnology has been proven over the past decade in countries with more than half of the world's population."

"What we need is courage by the leaders of those countries where farmers still have no choice but to use older and less effective methods. The Green Revolution and now plant biotechnology are helping meet the growing demand for food production, while preserving our environment for future generations" (ISAAA, 2009).

Case Study 1 – Insect Resistant (Bt) Brinjal /Eggplant in Bangladesh

Brief Description: The Bt brinjal project in Bangladesh may lay claim to be the first crop biotechnology transfer project to deliver a product that has already been commercialized by farmers. Bt brinjal was developed as an international public private partnership, between an Indian seed company Mahyco generously donating technology to the Bangladesh public sector R&D institute Bangladesh Agricultural Research Institute (BARI), facilitated by Cornell University led project ABSP-II and funded by USAID. Bangladesh approved Bt brinjal for commercial cultivation on 30 Oct 2013 and in record time – less than 100 days – on 22 January 2014 a group of small farmers planted the first commercial product in their own fields. In 2014, a total of 12 hectares of Bt brinjal were planted by 120 farmers and the area is expected to increase substantially in 2015. This feat would not have been possible without strong support for the project from the Government of Bangladesh and in particular the political will and support of the Minister of Agriculture, the Honourable Matia Chowdhury. Bt brinjal drastically reduces pesticide application, increases marketable yield and improves fruit quality. Farmers have successfully sold Bt brinjal fruits in the open market labelled as *"BARI Bt Begun #, no pesticide used"*. More specific information is provided below.

Country: Bangladesh
Crop: Brinjal/Eggplant
Area: ~50,000 hectares farmed by approx. 150,000 smallholder farmers – average holding of 0.3 hectare
Importance: The poor man's vegetable crop, known as "the queen of the vegetables"
Gene: *cry1Ac* gene from *Bacillus thuringiensis* (Bt)
Trait(s): Insect resistance (IR); imparts protection against the lethal insect pest fruit and shoot borer (*Leucinodes orbonalis*) which often requires small farmers to apply a polluting insecticide spray every other day and even then adequate control is not possible
Event: Elite Event EE-1
Technology Donor: the private sector company Mahyco, from India
Technology Recipient: Bangladesh Agricultural Research Institute (BARI)
Donor Funding Agency: USAID
Facilitator: Agricultural Biotechnology Support Program-II (ABSP-II) managed by Cornell University
Status of Approval: Approved for food, feed and environmental release on 30 Oct 2013 and commercialized in less than 100 days later on 22 January 2014
Varieties Approved: Brinjal-1 (Uttara), Bt Brinjal-2 (Kajla), Bt Brinjal-3 (Nayantara) and Bt Brinjal-4 (Iswardi/ISD 006)
Commercialization: 120 farmers planted Bt brinjal on 12 hectares in 2014
Number of Potential Beneficiary Farmers: 150,000 of the poorest and smallest farmers in Bangladesh which has a per capita of less than US$1,000 per annum.
Socio-Economic Impact: Increases marketable yield by at least 30% and reduces the number of insecticide applications by 70-90%, resulting in a net economic benefit of US$1,868 per hectare. This is equivalent to a gain of up to US$200 million per annum.

Case Study 2 – Herbicide Tolerant (HT) Soybean in Brazil

Brief Description: In 2010, the Brazilian regulator authority CTNBio approved the commercial cultivation of a new herbicide tolerant soybean variety developed through a public private partnership jointly executed by the private sector company BASF Germany and the public sector R&D institute EMBRAPA, the Brazilian Agricultural Research Cooperation. In this collaborative project, BASF provided EMBRAPA with the csr1-2 gene, which confers tolerance to the herbicide imidazolinone, whilst the Brazilian institution also provided an additional gene and was responsible for the insertion of the trait into well adapted soybean germplasm. EMBRAPA and BASF share the patent for the new varieties, which represent the first home-grown biotech crop developed through PPP and approved in Brazil. Commercialization in Brazil is waiting on final import approval from the EU. It is expected that the new HT soybean varieties will be commercialized in Brazil by 2016, increasing the choice of weed management options for Brazilian growers. More specific information is provided below.

Country: Brazil
Crop: Soybean
Area: ~31 million hectares
Importance: Most important export crop of Brazil
Gene: *csr1-2* from *Arabidopsis thaliana* conferring tolerance to imidazolinone herbicides
Trait(s): Herbicide tolerance
Event: BPS-CV127-9
Technology Provider: BASF, Germany/EMBRAPA, Brazil (there are 2 main patents supporting the product development, one gene from BASF and another from EMBRAPA = soy gene transfer
Technology Recipient: BASF, Germany/EMBRAPA, Brazil
Donor Funding Agency: BASF, Germany/EMBRAPA, Brazil
Facilitator/Collaborator: BASF, Germany/EMBRAPA, Brazil
Status of Approval: Approved for commercial cultivation in 2009 (December), but pending EU final import approval
Variety Approved: Varieties to be sold under the brand name Cultivance™
Commercialization: Expected planting as commercial crop in 2016
Potenial Beneficiaries include farmers, seed growers and consumers
Socio-Economic Impact: Cultivance™ expected to reach up to 20% of market share on 31 million hectares of soybean with an export value of US$17 billion

Case Study 3 – Drought Tolerant (DT) Sugarcane in Indonesia

Brief Description: In May 2013, Indonesia – the second largest (2.4 million tonnes, valued at US$1.6 billion) raw sugar importing country in the world, issued food and environmental safety certificates for the country's first home-grown genetically modified drought tolerant sugarcane. The biotech sugarcane variety "Cane PRG Drought Tolerant NX1-4T" was developed under a public private partnership between the Indonesian State-owned sugar company, PT. Perkebunan Nusantara XI (PTPN-11) and Ajinomoto Company, Japan in collaboration with Jember University in East Java, Indonesia. The drought tolerant sugarcane varieties can withstand water stress up to 36 days and under drought stress can yield substantially higher than the control variety BL-19; yield increases from 2 to 75% in the first planting, 14 to 57% in the first ratoon, and from 11 to 44% in the second ratoon. It is expected that the first home-grown drought tolerant sugarcane will be officially planted in Indonesia in 2015, pending approval of the product for feed. More specific information is provided below.

Country: Indonesia
Crop: Sugarcane
Area: ~450,000 hectares
Importance: Indonesia is the second largest sugar importing country in the world
Gene: *betA* from *Rhizobium meliloti*
Trait(s): Drought tolerance
Event: NX1-4T
Technology Provider: Ajinomoto, Japan
Technology Recipient: PT. Perkebunan Nusantara XI (PTPN-11), Indonesia
Donor Agency: Government of Indonesia
Facilitator/Collaborator: Jember University, East Java, Indonesia
Status of Approval: Approved for food and environmental release in 2013, pending feed approval
Variety Approved: Cane PRG Drought Tolerant NX1-4T
Commercialization: Expected commercial planting in 2015

Case Study 4 – Drought Tolerant (DT) Maize for Africa (WEMA Project)

Brief Description: Monsanto donated the biotech drought tolerant (DT) maize technology (MON 87460), DroughtGard™ to the public sector agriculture R&D institutions in five countries in Sub Saharan Africa including South Africa, Kenya, Uganda, Mozambique, and Tanzania through a public private partnership project entitled **"Water Efficient Maize for Africa (WEMA)"**. WEMA is coordinated by the African Agricultural Technology Foundation (AATF) based in Nairobi in collaboration with Monsanto and CIMMYT for further technology development. The project is funded jointly by the Gates Foundation, the Howard G. Buffett Foundation and USAID. The first stacked biotech insect resistant/ drought tolerant (Bt/DT) maize hybrids are expected to be available to farmers and commercialized (subject to regulatory approval) as early as 2017. South Africa is expected to be the first country to deploy the technology in 2017, followed by Kenya and Uganda which are expected to conduct confined field trials (CFT) of the stack next year, 2015. The three countries have conducted CFTs with DT maize for at least 5 seasons (Uganda 5th, Kenya 6th and South Africa 7th season) with very encouraging results. Kenya is in its 3rd season CFT for Bt maize (Mon 810 also donated by Monsanto subsequent to initiating the project) and Uganda in the 2nd season field testing. In Mozambique, a revised Biosafety decree and implementing regulations received approval by the Council of Ministers in October 2014, and the country is due to initiate WEMA CFTs in 2015. Tanzania has made substantive progress towards amendment of the 2009 Biosafety regulations to pave the way for the long-awaited CFTs. It is projected that the WEMA stacked DT/BT maize hybrids may yield up to 20 to 35% more grain than other commercial hybrids under moderate drought, resulting in an additional 2 to 5 million MT of maize to feed 14 to 21 million Africans.

Country: South Africa, Kenya, Uganda, Tanzania and Mozambique
Crop: Maize
Area: ~8 million hectares in the five countries
Importance: Africa grows 90% of its maize under rainfed conditions and up to 25% of the area suffers from frequent droughts
Gene: Cold shock protein gene (*CspB*) from *Bacillus subtilis*
Trait(s): Drought tolerance
Event: Event MON87460 to be deployed as a stacked hybrid maize, also featuring a Bt gene (MON 810) for insect control also donated by Monsanto subsequent to the initiation of the project; the DT event is the same as that deployed in the 50,000 hectares of biotech drought tolerant maize in the US in 2013, which increased 5.5-fold to 275,000 hectares in the US in 2014.
Technology Provider: Monsanto, USA
Technology Recipients: South Africa, Kenya, Uganda, Mozambique and Tanzania
Donor Funding Agencies: The Gates Foundation, the Howard G. Buffet Foundation & USAID
Facilitators: African Agricultural Technology Foundation (AATF), NARIs in 5 WEMA countries, CIMMYT
Status of Approval: First deployment of stacked DT/BT expected in South Africa in 2017, followed by Kenya and Uganda who are expected to conduct confined field trials (CFT) of the stacked product next year, 2015. Revised Biosafety decree and implementing regulations endorsed in Mozambique which paves the way for CFTs to be conducted in 2015, and positive discussion on amendment of biosafety regulations proceeding in Tanzania.
Commercialization: To begin (subject to regulatory approval) in South Africa in 2017
Socio-Economic Impact: Could increase maize production by up to 2 to 5 million tons under moderate drought, to feed about 14 to 21 million people.

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Appendices

Appendix 1. Global Crop Protection Market, 2014

US$M	Herbicides	Insecticides	Fungicides	Others	Biotech	Total
North America	7,526	2,058	1,583	540	11,694	23,402
West Europe	3,713	1,440	3,749	716	5	9,623
East Europe	1,250	676	710	148	5	2,790
Japan	1,418	1,347	1,102	124	0	3,991
Australia	1,349	502	293	84	28	2,256
Industrial Countries	**15,256**	**6,023**	**7,438**	**1,613**	**11,732**	**42,062**
Latin America	5,976	3,778	4,008	591	3,285	17,639
Rest of Far East	2,350	2,547	2,476	241	404	8,019
Rest of World	994	2,002	875	116	642	4,628
Developing Countries	**9,320**	**8,327**	**7,359**	**948**	**4,331**	**30,286**
Total	**24,576**	**14,351**	**14,797**	**2,561**	**16,063**	**72,348**

Source: Cropnosis Agrochemical Service, 2014

Appendix 2a. Seed Exports (FOB) of Selected Countries, 2012 (with over 100 Million US$ Market)

Country	Field Crops	Vegetable Crops	Total
France	1,437	349	1,804
Netherlands	256	1,225	1,583
USA	930	529	1,531
Germany	638	58	727
Chile	218	150	388
Hungary	374	11	385
Canada	317	6	323
Italy	198	116	315
Denmark	221	42	265
China	79	158	251
Romania	217	1	218
Belgium	203	3	208
Mexico	175	27	203
Brazil	151	14	165
United Kingdom	120	21	151
Argentina	135	15	150
Others	1,123	722	8,667
Total	**6,792**	**3,447**	**10,543**

Appendix 2b. Seed Imports (FOB) of Selected Countries, 2012 (with over 100 Million US$ Market)

Country	Field Crops	Vegetable Crops	Total
United States	837	369	1,312
Germany	590	90	700
France	540	137	687
Netherlands	263	373	685
Italy	242	170	422
Spain	176	197	374
Russian Federation	310	58	373
Mexico	133	221	355
United Kingdom	202	70	287
China	143	111	268
Ukraine	238	30	268
Japan	98	113	231
Belgium	195	31	228
Canada	133	75	223
Turkey	64	122	188
Poland	122	50	175
Romania	129	16	147
Hungary	125	14	139
Brazil	50	67	120
Others	1,633	933	2,567
Total	**6,223**	**3,247**	**9,749**

Source: International Seed Federation, 2012 http://www.worldseed.org/isf/seed_statistics.html

Appendix 3. Estimated Value of the Domestic Seed Market in Selected Countries for the year 2012 (Updated June 2013).

Country	Value (USD million)	Country	Value (USD million)
USA	12,000	Morocco	140
China	9,950	Switzerland	140
France	2,800	Bulgaria	120
Brazil	2,625	Chile	120
Canada	2,120	Nigeria	120
India	2,000	Serbia	120
Japan	1,350	Slovakia	110
Germany	1,170	New Zealand	100
Argentina	990	Uruguay	96
Italy	767	Ireland	80
Turkey	750	Paraguay	80
Spain	660	Portugal	80
Netherlands	590	Algeria	70
Russian Federation	500	Kenya	60
United Kingdom	450	Iran	55
South Africa	428	Israel	50
Australia	400	Tunisia	45
Republic of Korea	400	Bolivia	40
Mexico	350	Colombia	40
Czech Republic	305	Slovenia	40
Hungary	300	Peru	30
China, Taiwan	300	Zimbabwe	30
Poland	280	Malawi	26
Sweden	250	Libya	25
Romania	220	Saudi Arabia	20
Denmark	218	Zambia	20
Greece	200	Philippines	18
Belgium	185	Ecuador	15
Finland	160	Tanzania	15
Austria	145	Uganda	10
Egypt	140	Dominican Republic	7

Total US$44,925 million

The commercial world seed market is assessed at approximately 45 billion dollars

Source: http://www.worldseed.org/isf/seed_statistics.html

Appendix 4. Arable Land per Capita in Developing Asian Countries

Country	Arable Land (Million Ha)	Population (Million)	Arable Land/Capita
Cambodia	3.9	14.3	0.27
Thailand	16.4	69.5	0.24
Laos	1.4	6.3	0.22
Myanmar	10.4	48.3	0.22
India	174.2	1,241.5	0.14
Pakistan	21.5	176.7	0.12
Indonesia	24.8	242.3	0.10
North Korea	2.3	24.5	0.09
China	113.8	1,347.6	0.08
Vietnam	6.9	88.8	0.08
Timor-Leste	0.1	1.2	0.08
Malaysia	1.8	28.9	0.06
Nepal	2.3	30.5	0.07
Philippines	5.4	94.9	0.06
Bangladesh	8.7	150.5	0.06
Sri Lanka	1.2	21.0	0.06
Reference Countries			
Australia	42.2	22.6	1.90
South Korea	1.5	48.4	0.03
Japan	4.4	126.5	0.03
Argentina	38.0	40.8	0.93
South Africa	12.2	50.5	0.24
Brazil	70.6	196.7	0.35
USA	164	313.1	0.52

Source: Pocket World in Figures 2014, The Economist.

Appendix 5. Estimated Population of the 28 Biotech Countries in 2050, 2100

	Country	Population in 2014*	Estimated Population in 2050**	Estimated Population in 2100**
1	USA	313.1	400.8	462.1
2	Brazil	196.7	231.1	194.5
3	Argentina	40.8	51.0	50.4
4	India	1,214.5	1,620.0	1,546.8
5	Canada	34.3	45.2	50.9
6	China	1,347.6	1,384.9	1,085.6
7	Paraguay	6.6	10.4	11.8
8	Pakistan	176.7	271.1	263.3
9	South Africa	50.5	63.4	64.1
10	Uruguay	3.4	3.6	3.3
11	Bolivia	10.1	16.6	19.5
12	Philippines	94.9	157.1	187.7
13	Australia	22.6	33.7	41.5
14	Burkina Faso	17.0	40.9	75.3
15	Myanmar	48.3	58.6	47.4
16	Mexico	114.8	156.1	139.8
17	Spain	46.5	48.2	41.7
18	Colombia	46.9	62.9	60.2
19	Sudan	33..6	77.1	116.1
20	Honduras	7.8	13.5	15.6
21	Chile	17.3	20.8	18.8
22	Portugal	10.7	9.8	7.4
23	Cuba	11.3	9.4	5.4
24	Czech Republic	10.5	11.2	11.1
25	Romania	21.4	17.8	12.6
26	Slovakia	5.5	4.9	3.9
27	Costa Rica	4.7	6.2	5.3
28	Bangladesh	150.5	201.9	182.2
	World	**6,974.0**	**9,550.9**	**10,853.8**

Source:
* Pocket World in Figures 2014, The Economist
** United Nations, Department of Economic and Social Affairs. Population Division.
http://www.un.org/en/development/desa/population/publications/pdf/trends/WPP2012_Wallchart.pdf

Appendix 6. Commercial Release of Different Bt Cotton Varieties and Hybrids in Pakistan between 2010 and 2014

Event	Variety (*hybrid)	Developer	Status
cry1Ac gene (MON531 event)	IR-NIBGE-3701	Nuclear Institute for Biotechnology and Genetic Engineering (NIBGE), Faisalabad	Approved in 2010
cry1Ac gene (MON531 event)	Ali Akbar-703	M/s Ali Akbar Seeds, Multan	Approved in 2010
cry1Ac gene (MON531 event)	MG-6	M/s Nawab Gurmani Foundation	Approved in 2010
cry1Ac gene (MON531 event)	Sitara-008	M/s Nawab Gurmani Foundation	Approved in 2010
fusion gene (*cry1Ac* and *cry1Ab*)/GFM event	GN-2085* (hybrid)	M/s Guard Agricultural Research Services, Lahore	Approved in 2010 (two year approval, DUS trial data to be submitted to FSC&RD)
cry1Ac gene (MON531 event)	IR-NIBGE-1524	NIBGE, Faisalabad	Approved in 2010; Renewed in 2012
cry1Ac gene (MON531 event)	Ali Akbar-802	M/s. Ali Akbar Seeds, Multan	Renewed in 2012
cry1Ac gene (MON531 event)	Neelum-121 (NS 121)	M/s. Neelum Seeds, Jahanian, Vehari	Approved in 2010; Renewed in 2012
cry1Ac gene (MON531 event)	FH-114	Cotton Research Institute, CRI, Faisalabad	Approved in 2012
cry1Ac gene (MON531 event)	FH-113	Cotton Research Institute, CRI, Faisalabad	One Year Approved in 2010
cry1Ac gene (MON531 event)	CIM-598	Central Cotton Research Institution (CCRI), Multan	Approved in 2012
cry1Ac gene (MON531 event)	SITARA-009	M/s Agri Farm Services, Multan	Approved in 2012
cry1Ac gene (MON531 event)	A-ONE	M/s Weal-AG Corporation, Multan	Approved in 2012
cry1Ac gene (MON531 event)	TARZAN-1	Four Brothers Seeds Corporation Pakistan Pvt. Ltd., Multan	One year Approval in 2012 (Conditional approval for field performance/monitoring) Under Cultivation
cry1Ac gene (MON531 event)	NS-141	M/s Neelum Seeds, Jahanian, Vehari	Same as above
cry1Ac gene (MON531 event)	IR-NIBGE-3	NIBGE, Faisalabad	Same as above
cry1Ac gene (MON531 event)	MNH-886	Cotton Research Station (CRS), Multan	Same as above
cry1Ac gene (MON531 event)	VH-259	Cotton Research Station (CRS), Vehari	Approved in 2013 Under Cultivation
cry1Ac gene (MON531 event)	BH-178	Cotton Research Station (CRS), Bahawalpur	Approved in 2013 Under Cultivation

Appendix 6. Commercial Release of Different Bt Cotton Varieties and Hybrids in Pakistan between 2010 and 2014

Event	Variety (*hybrid)	Developer	Status
cry1Ac gene (MON531 event)	CIM-599	Central Cotton Research Institute, (CCRI), Multan	Approved in 2013 Under Cultivation
cry1Ac gene (MON531 event)	CIM-602	Central Cotton Research Institute, (CCRI), Multan	Approved in 2013 Under Cultivation
cry1Ac gene (MON531 event)	FH-118	Cotton Research Institute (CRI), Bahawalpur	Approved in 2013 Under Cultivation
cry1Ac gene (MON531 event)	FH-142	Cotton Research Institute (CRI), Bahawalpur	Approved in 2013 Under Cultivation
cry1Ac gene (MON531 event)	IR-NIAB-824	Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad	Approved in 2013 Under Cultivation
cry1Ac gene (MON531 event)	IUB-222	Islamia University, Bahawalpur	Approved in 2013 Under Cultivation
cry1Ac gene (MON531 event)	CEMB-33	Center of Excellence in Molecular Biology (CEMB), University of Punjab, Lahore	Approved in 2013 Under Cultivation
cry1Ac gene (MON531 event)	SAYBAN-201	M/s Auriga Seeds, Lahore	Approved in 2013 Under Cultivation
cry1Ac gene (MON531 event)	Sitara-11M	M/s Agri Farm Services, Multan	Approved in 2013 Under Cultivation
cry1Ac gene (MON531 event)	A-555	M/s Wheal AG, Multan	Approved in 2013 Under Cultivation
cry1Ac gene (MON531 event)	KZ-181	M/s Kanzo Seeds, Multan	Approved in 2013 Under Cultivation
cry1Ac gene (MON531 event)	Tarzan-II	M/s Four Brothers Seeds, Multan	Approved in 2013 Under Cultivation
cry1Ac gene (MON531 event)	CA-12	M/s Ali Akbar Seeds, Lahore	Approved in 2013 Under Cultivation

Source: Punjab Seed Council (PSC), 2010 & 2012, Pakistan Today, 2011 & 2012; Ministry of Textile Industry, 2012; PSC, 2013, NBC, 2014; PCCC, 2014; Analyzed and compiled by ISAAA, 2014.

Appendix 7. A List of Selected Biotech Crops at Various Stages of Field Testing in Different Countries

Crop	Trait(s)	Attributes	Institutions	Country
Apple	AP	Anti-Browning and Anti Bruising	Okanagan Specialty	Canada
Apple	DR	Blight resistant	ETH Zurich & JKI	Germany & Switzerland
Alfalfa	AP	Low Lignin	Monsanto, Forage Genetic International & Pioneer	USA
Banana	QT	Enhanced Vitamin-A	QUT, NARO & Gates Foundation	Uganda
Banana	DR	Banana Xanthomonas Wilt	AATF, Academia Sinica, NARO, IITA, Gatsby Foundation & USAID	Uganda
Banana	IR/NR	Parasitic, weevil & nematode resistant	NARO, UC, UP, Rockefeller Foundation & USAID	Uganda
Camelina/ False flex	QT	Enhanced Omega-3	Rothamsted Research	UK
Canola	HT	Multiple mode herbicide tolerant	Pacific Seeds	Australia
Canola	HT	Multiple-mode herbicide tolerant	Bayer, Monsanto & Pioneer	USA, Canada
Canola	QT	Enhanced Omega-3	Cargill & BASF	USA
Cassava	VR	Brown streak virus resistant	Danforth Center, Howard Buffet Foundation, Gates Foundation, NARS, Monsanto, ETH Zurich & USAID	Kenya & Uganda
Cassava	QT	Enhanced Vitamin-A	AATF, KARI & NARO	Nigeria, Kenya & Uganda
Citrus	DR/HLB/ ACP	Citrus Greening	USDA & HLB-MAC	USA
Chickpea	IR	Pod Borer Resistant	AAU, DBT & Sungro Seeds	India
Cotton	IR/HT	Stacked insect resistant and herbicide tolerant	KALRO, INERA & Monsanto	Cameroon, Burkina Faso, Ghana, Kenya, Malawi & Togo
Cotton	IR/HT	Stacked insect resistant and herbicide tolerant	Monsanto	Pakistan
Cotton	IR/HT	Stacked insect resistant and herbicide tolerant	Mahyco & Monsanto	India
Cotton	IR/HT	Triple gene insect resistant & herbicide tolerant	Monsanto	India
Cotton	IR/HT	Multiple-mode insect and herbicide tolerant	Bayer Cropscience, Dow Agroscience & Monsanto	USA

Appendix 7. A List of Selected Biotech Crops at Various Stages of Field Testing in Different Countries

Crop	Trait(s)	Attributes	Institutions	Country
Cotton	IR/HT	Lygus Control	Monsanto	USA
Cotton	QT	Ultra low Gossypol	TAMU	USA
Corn	QT	High Phytase	Origin Agritech & CAAS	China
Corn	IR/DT	Double gene insect resistant & drought tolerant	AATF, CIMMYT, Gates Foundation, Buffet Foundation, Monsanto, NARS & WEMA	Kenya, Uganda & South Africa
Corn	IR/HT	Stacked insect resistant and herbicide tolerant	Pioneer & Monsanto	India
Corn	IR/HT	Stacked insect resistant & herbicide tolerant	Pioneer & Monsanto	Indonesia
Corn	IR/HT	Stacked insect resistant & herbicide tolerant	Pioneer, Monsanto & Syngenta	Pakistan
Corn	IR/HT	Stacked insect resistant and herbicide tolerant	Pioneer & Monsanto	South Africa
Corn	IR/HT	Multiple-mode insect & herbicide resistant	Dow Agroscience, Monsanto, Pioneer & Syngenta	USA
Corn	NUE	Nitrogen use efficiency	Pioneer & Syngenta	USA
Corn	ST	Stress tolerance and yield enhancement	Pioneer, Monsanto & BASF	USA
Corn	IR/HT	Stacked insect resistant & herbicide tolerant	Pioneer, Monsanto & Syngenta	Vietnam
Cowpea	IR	Pod borer resistant	AATF, CSIRO, IITA, Monsanto, NARS, NGICA, PBS, Rockefeller Foundation & USAID	Burkina Faso, Ghana & Nigeria
Groundnut	VR/FR	Groundnut rosette virus, Aspergillus flavus & aflatoxin	ICRISAT	India
Mustard	AP	Heterosis exploitation	DU & NDDB	India
Pigeon pea	IR	Pod borer resistant	ICRISAT	India
Potato	DR	Late blight resistant	WU, VIB & GU	Netherlands & Belgium
Potato	VR	Potato Virus Y (PVY) resistant	INBEBI/CONICET-UBA & Tecnoplant-SIDUS SA	Argentina
Potato	DR	Late blight resistant	BARI, PRC, ABSP-II & USAID	Bangladesh
Potato	DR	Late blight resistant	IAARD, ICABIOGRAD, IVEGRI, ABSP-II & USAID	Indonesia

Appendix 7. A List of Selected Biotech Crops at Various Stages of Field Testing in Different Countries

Crop	Trait(s)	Attributes	Institutions	Country
Potato	DR	Late blight resistant	CPRI, ICAR, ABSP-II & USAID	India
Potato	QT	Anti-Browning, Anti Bruising & Low Acrylamide	J.R. Simplot Company	USA
Rice	IR	Insect resistant	HuAU	China
Rice	NUWEST	Nitrogen use efficiency, Water efficient & salt tolerant	AATF, Arcadia biosciences, CIAT, Japan Tobacco, NARS, UC, DFID & USAID	Ghana & Uganda
Rice	IR	Insect resistant	Mahyco	India
Rice	NUE	Nitrogen use efficiency	Mahyco	India
Rice	QT	High iron	CU & DBT	India
Rice	QT	Enhanced Vitamin-A	IRRI	Bangladesh, India, Indonesia & Philippines
Rice	QT	Enhanced Vitamin-A	IRRI & PhilRice	Philippines
Rice	IR/HT	Multiple gene insect resistant & herbicide tolerant	Bayer Cropscience & Pioneer	USA
Safflower	QT	High Oleic acid	CSIRO	Australia
Sorghum	QT	Enhanced Vit A, Bio-available Zinc and Iron	Africa Harvest, Pioneer Hi-Bred, a DuPont business and KALRO; IAR and NABDA	Kenya, Nigeria
Soybean	HT	Herbicide tolerant	EMBRAPA & BASF	Brazil
Soybean	HT/QT	Herbicide tolerant & modified fatty acid	Pioneer	South Africa
Soybean	HT	Multiple mode herbicide tolerant	Bayer Cropscience, Dow Agroscience, Monsanto, Pioneer & Syngenta	USA
Soybean	QT	SDA Omega-3 & Zero trans-fat oil	Monsanto	USA
Soybean	AP	Yield enhancement	Monsanto & BASF	USA
Soybean	NR	Soybean cyst nematode tolerant	Bayer, BASF, Syngenta & Monsanto	USA
Soybean	DR/AP	Asian soybean rust tolerant and increased oil & improved feed efficiency	Pioneer	USA
Soybean	DR	Disease resistance	Syngenta	USA
Sugar beet	AP/DT	High yielding & drought tolerant	KWS & BASF	Germany
Sugarcane	IR/HT	Insect resistant & herbicide tolerant	SRA & Monsanto	Australia & USA

Appendix 7. A List of Selected Biotech Crops at Various Stages of Field Testing in Different Countries

Crop	Trait(s)	Attributes	Institutions	Country
Sugarcane	AP	High yielding & drought tolerant	CTC & BASF	Brazil
Sugarcane	DT/QT	Drought tolerant & high sugar content	PTPN-XI, JU & Ajinomoto	Indonesia
Tomato	AP	Purple color	Jonn Innes Centre	Canada
Wheat	DT	Drought tolerant	CSIRO & VDEPI	Australia
Wheat	QT	Improved grain quality	MU	Australia
Wheat	DR	Powdery mildew resistance	CAS	China
Wheat	DR	Fusarium resistant	CAAS	China
Wheat	VR	Yellow mosaic resistant	CAAS	China
Wheat	DT/DR	Drought tolerant and disease resistant	AGERI	Egypt
Wheat	IR	Aphid Resistant	Rothamsted Research	UK
Wheat	HT	Multiple mode herbicide tolerant	Monsanto	USA

Source: Analyzed and compiled by ISAAA, 2014.

Legend (Trait): ACP-Asian Citrus Psyllid; AP-Agronomic Performance; IR-Insect Resistance; DR-Disease Resistance; FR- Fungal Resistance; HLB- Huanglongbing ; HT-Herbicide Tolerance; NE- Nutrition Enhancement; NR-Nematode resistance; NUE- Nitrogen Use efficiency; NUWEST-Nitrogen Use Efficiency, Water Efficient & Salt Tolerant; QT-Quality Trait; ST- Stress tolerance and VR-Virus Resistance.

Acronyms (Developer): AATF-Africa Agricultural Technology Foundation; ABSPII-Agricultural Biotechnology Support Project; AAU- Assam agricultural University, India; ABS- Africa Biofortified Sorghum; AGERI- Agricultural Genetic Engineering Research Institute, Egypt; AU- Adelaide University, Australia; BARI- Bangladesh Agricultural Research Institute; CAAS- Chinese Academy of Agricultural Sciences; CAS-Chinese Academy of Sciences; CONICET-Consejo Nacional de Investigaciones Científicas y Técnicas, Argentina; CIAT- Centro Internacional de Agricultura Tropica; CPRI-Central Potato Research Institute, India; CSIRO- Commonwealth Scientific and Industrial Research Organization, Australia; CTC- Centro de Tecnologia Canavieira, Brazil; CU-Calcutta University, India; DU- Delhi University, India; DBT- Department of Biotechnology, India; DFID-Department for International Development, UK; EMBRAPA- Empresa Brasileira de Pesquisa Agropecuária, Brazil; GU-Ghent University, Belgium; HuAU- Huazhong Agricultural University, China; ICAR-Indian Council of Agricultural Research, India; IITA- International Institute of Tropical Agriculture; INERA-Institut Nationale d'Economie Rurale, Burkina Faso; ICRISAT- International Crops Research Institute for the Semi-Arid-Tropics; INGEBI-Instituto de Investigaciones en Ingeniería Genética y Biología Molecular, Argentina; IRRI- International Rice Research Institute, IAARD-Indonesian Agency for Agricultural Research and Development; IAR-Institute for Agricultural Research, Nigeria; ICABIOGRAD-Indonesian Center for Agricultural Biotechnology and Genetic Resources Research and Development; IVEGRI- Indonesian Vegetable Research Institute; JKI- Julius Kühn Institute, Germany; JU- Jamber University, Indonesia; KARI- Kenya Agricultural Research Institute; KALRO- Kenya Agricultural and Livestock Research Organization; MU- Murdoch University , Australia; NARS-National Agricultural Research Systems; NARO- National Agricultural Research Organization; NDDB- National Dairy Development Board, India; NGICA- Network for the Genetic Improvement of Cowpea for Africa; PBS-Program for Biosafety Systems; PRC-Potato Research Center, Bangladesh; PhilRice- Philippines Rice Research Institute; PTPN XI- PT. Perkebunan Nusantara XI, Indonesia; QUT-Queensland University of Technology, Australia; SRA- Sugar Research Australia; TAMU- Texas A&M University; UC- University of California, USA; UP- University of Pretoria, South Africa; USAID- United States Agency for International Development; USDA- United States Department of Agriculture; VDEPI- Victorian Department of Environment & Primary Industries, Australia; VIB- Vlaams Instituut voor Biotechnologie, Belgium; WU-Wageningen University, Netherlands and WEMA- Water Efficient Maize for Africa.

Appendix 8. Miscellaneous Data and Conversions

Source: Iowa State University (Extension and Outreach)
https://www.extension.iastate.edu/agdm/wholefarm/html/c6-80.html

Weights

1 bushel corn/canola (56 lb) = 25.40 (~25) kilograms
1 bushel wheat/soybeans (60 lb) = 27.22 (~27) kilograms
1 quintal = 3.937 (~4) bushels corn (56 lb bu)
1 quintal = 3.674 (~3.7) bushels wheat/soybeans (60 lb bu)
1 metric ton = 39.37 (~40) bushels corn /canola (56 lb bu)
1 metric ton = 36.74 (~37) bushels wheat/soybeans (60 lb bu)

Grain yields

A corn yield of 200 bushels per acre is first expressed by weight (200 bu @ 56 lb/bu = 11,200 lbs) and then converted to kilograms (11,200 lbs * .4536 kg/lb = 5,080 kg). Because a hectare is equal to 2.471 acres, it means that 200 bu/ac is equal to about 12,553 kg/ha (5,080 kg/ac x 2.471 ac/ha = 12,553 kg/ha). This also translates into 126 quintals per hectare (200 bushels per acre x .63 quintals/hectare) and 12.55 metric tons per hectare (200 bushels per acre x .0628 metric tons/hectare)

Corn/canola (56lb/bu)

1 kilogram/hectare (kg/ha) = .0159 (~.016) bushels/acre
1 bushel/acre = 62.77 (~63) kilograms/hectare
1 quintal/hectare (q/ha) = 1.593 (~1.6) bushels/acre
1 bushel/acre = .6277 (~.63) quintals/hectare
1 metric ton/hectare (MT/ha) = 15.93 (~16) bushels/acre
1 bushel/acre = .0628 (~.06) metric tons/ hectare

Wheat/soybeans (60# bu)

1 kilogram/hectare (kg/ha) = .0149 (~.015) bushels/acre
1 bushel/acre = 67.25 (~67) kilograms/hectare
1 quintal/hectare = 1.487 (~1.5) bushels/acre
1 bushel/acre = .6725 (~.67) quintals/hectare
1 metric ton/hectare = 14.87 (~15) bushels/acre
1 bushel/acre = .0673 (~.07) metric tons/hectare

Rate

Application rates are often given in weight of material per unit of area covered (pounds per acre) or volume of material per unit of area covered (quarts per acre).

1 kilogram/hectare (kg/ha) = .8922 (~.9) pounds/acre
1 pound/acre = 1.121 (~1.1) kilograms/hectare
1 liter/hectare (L/ha) = .4276 (~.4) quarts/acre
1 quart/acre = 2.338 (~2.3) liters/hectare

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